Marine Physical Laboratory

Preliminary Analysis of the FLIP Array Data from the NOBS Experiment

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The initial examination of the data shows that a total of 36 vertical line array (VLA) hydrophones and all four channels of four ocean bottom seismometers (OBS) provided useable data. The quality of the recorded data is variable, but remains rather high for extended periods of time, especially for the 10 hours of data on tape 7. Analysis of tape 7's data indicates that the calibrated ambient noise spectra estimated from the VLA hydrophone data agree well with predicted noise levels in moderate to heavy shipping regions. At times, these spectra contain a peak centered at 18 Hz, which is probably indicative of the presence of whales. In addition, ship-generated signals are clearly visible in the spectra at those times when surface ship sightings were noted in the experiment log.

Finally, large amplitude signals of unknown origin were observed in the root mean squared (RMS) time series plots for all functioning data channels. Plots of the time series of the original data indicate that the large amplitude signals, of 20-sec to one-min duration, are preceeded by a smaller arrival on the OBS geophones, but this "precursor" is not present in the OBS hydrophone data nor on the VLA hydrophones. From spectral ratio plots, the energy of the large arrivals occur in a frequency band from 8 to 30 Hz, with a peak around 10 Hz. The coherence function estimates between the OBS hydrophones and between the VLA hydrophones for the large arrivals are consistent with a horizontally propagating acoustic wave. Therefore, one possibility is that these arrivals are water-borne phases from regional earthquakes since the experiment was conducted in a seismically active area.

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ABSTRACT

Preliminary analysis of the data collected by the array suspended below R/P FLIP (FLoating Instrument Platform) during the Noise Over Basalts and Sediments (NOBS) experiment are presented in this report. The deployment location was at 43° 42′ N, 125° 59′ W, over the east flank of the Juan de Fuca ridge, in 3-km-deep water. This report gives a description of the FLIP array, a summary of the tape log kept aboard FLIP, a summary of the quality of the data collected, and the results of some initial data analysis.

The initial examination of the data shows that a total of 36 vertical line array (VLA) hydrophones and all four channels of four ocean bottom seismometers (OBS) provided useable data. The quality of the recorded data is variable, but remains rather high for extended periods of time, especially for the 10 hours of data on tape 7. Analysis of tape 7's data indicates that the calibrated ambient noise spectra estimated from the VLA hydrophone data agree well with predicted noise levels in moderate to heavy shipping regions. At times, these spectra contain a peak centered at 18 Hz, which is probably indicative of the presence of whales. In addition, ship-generated signals are clearly visible in the spectra at those times when surface ship sightings were noted in the experiment log.

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May 11, 1992

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I. INTRODUCTION

During the months of September and October, 1991, the NOBS (Noise on Basalts and Sediments) experiment, a collaborative project between the Scripps Institution of Oceanography, the University of Washington, and Boise State University, was conducted on the east flank of the Juan de Fuca ridge and the adjoining Cascadia basin. One objective of the NOBS project is to compare simultaneous measurements of the ocean surface wave spectra and the directionality and spatial coherence of very low frequency noise (less than 5 Hz) at the ocean floor in order to understand the mechanisms by which non-linear ocean surface wave-wave interactions are coupled into different types of ocean bottoms. The project site was chosen due to the proximity (within tens of kilometers) of two very different ocean bottom geologic settings; a relatively smooth basaltic seafloor and a seafloor covered by sediment thicknesses of up to 500 meters.

A second objective is to understand the sources, modes of propagation and distribution of low frequency (~5 - 125 Hz) noise near the ocean bottom, as well as to evaluate a possible depth dependence of ambient noise. As part of the NOBS experiment, the Floating Laboratory Instrument Platform (FLIP) was stationed at 43° 00′ N, 125° 00′ W, approximately 165 km southwest of Newport, Oregon. A multi-sensor array, which is described below, was suspended from FLIP. The purpose of this report is to present the results of an intial analysis of the data collected by this array.

II. DESCRIPTION OF ARRAY DEPLOYED FROM FLIP

A 645-m vertical array of 44 hydrophones, each separated by 15 m, was suspended from FLIP, with the lowermost element located about 15 m above the ocean bottom. Except for the bottom four hydrophones, vibration isolators were used to mechanically decouple the hydrophones from the array strength cable in order to reduce the effects of strum. Connected to the lower end of the vertical hydrophone array was an array of 16 ocean bottom seismometers (OBS's). The OBS's were placed on the ocean bottom in an approximate circle below FLIP (re Figure II.1). The inter-OBS separation was 75 m, except for two of the elements which were separated by 15 m. Each of the eight OBS processors formatted the data from two adjacent OBS's (indicated by alternating black and white pairs in Figure II.1). Each OBS contains three mutually orthogonal geophones enclosed in a glass sphere and a hydrophone mounted outside the sphere. Therefore, a total of 108 channels (16 OBS's x 4 channels/OBS + 44 hydrophones) were sampled at 250 Hz and telemetered up to the digital recording system on FLIP.

III. SUMMARY OF THE FLIP TAPE LOG

Figure III.1 is a summary of the tape log kept aboard FLIP. All times are reported in Greenwich Mean Time. To obtain local time, subtract seven hours.

IV. SUMMARY OF DATA COLLECTION

Approximately 35 hours of data, recorded on six Exabyte (model 8500) tapes numbered 3 through 8, were collected on Julian Days 280 and 281 (7th and 8th of October, 1991). Table 1 lists the time periods spanned by each exabyte tape.

TABLE 1

TAPE No.	JULIAN DAY	TIME (GMT)	TOTAL TIME	No. RECORDS	ARRAY STATUS	SHIP No. *
3	280	07:36-16:16	8 hrs, 40 min	109,875	Deploying	1,2
4	280	16:27-21:24	4 hrs, 57 min	62,502	Adjusting/cal	3
5	280-1	21:24-00:15	2 hrs, 41 min	36,143	Adjusting/cal	-
6	281	00:23-02:00	1 hr, 37 min	18,562	No Adjust	4
7	281	02:00-11:56	9 hrs, 56 min	126,000	No Adjust	4
8	281	11:56-16:40	4 hrs, 44 min	55,263	Recovering/cal	5

* There were a total of 5 passing ships recorded in the log (Figure III.1). The time duration of the presence of the ships is indicated in Figures V.1 through V.4.

A. Status of Array During Data Collection

Although there were 108 channels of data being recorded, for most of the time only the two OBS processors nearest FLIP (procs 23 and 3e collecting the data of four OBS's enclosed by a dotted circle in Figure II.1) and the five vertical hydrophone processors farthest from FLIP (procs 3c, 3a, 26, 31, and 27) were actually transmitting useable data, thereby providing 52 good data channels (2 OBS processors x 2 OBS's/processor x 4 channels/OBS + 5 vertical hydrophone processors x 8 channels/processor - 4 channels since the bottom vertical hydrophone array processor contained only 4 hydrophones).

During the last 15 hrs or so of the collecting period (tapes 7 and 8), the entire array was in place and anywhere from 0 to 8 processors were transmitting usable data. Tape 7 (JD 281, 02:00-11:56) contains data recorded during a time when the array was transmitting the highest quality data, i.e., all 52 channels were recorded with relatively few processor I.D. errors (re Section V).

B. Organization of Data on Tapes

The data is written onto tape in 16,252-byte records. Each record contains 71 samples from each channel. Since each channel is sampled every 4 msec, then each record represents 0.284 seconds (71 samples/250 samples/sec). Within each 4 msec sampling period, the eight elements associated with each processor are sampled sequentially, resulting in a 0.5 msec delay between the samples from successive channels of any given processor.

V. DATA QUALITY

This section contains a summary of the quality of data on each Exabyte tape. Data quality is judged by the frequency of processor I.D. errors found while scanning the record headers of each tape and noting changes and/or errors in processor I.D. numbers. Additionally, the record headers were scanned to determine when changes were made in the array variable gain (upon command from FLIP, re Table 2 located after Figure III.1) and to evaluate the performance of the GOES clock by searching for times when the clock was not incrementing properly (Table 3, located after Table 2). Some of the clock malfunctions correspond to times when the electrical power to the array was turned off. Figures V.1 through V.10 delineate times of differing data quality on the tapes based on the number of processors transmitting usable/extractable data during those times. Figures V.1 through V.4 are maps of the processor I.D. errors/data quality and are scaled horizontally to show the relative durations of each of the tapes. Note that Figure V.2 contains information for tapes 4, 5, and 6. Figures V.5 through V.10 are the same mappings enlarged to show the regions in greater detail. Note, however, that they do not show the relative lengths of the tapes. Tape 7 contains the highest quality data.

VI. RESULTS OF INITIAL DATA PROCESSING

The initial data processing focused on tape 7 since it had the fewest processor I.D. errors and therefore contained the most easily extracted data.

A. RMS Time Series Plots

A summary of the data on tape 7 was compiled by creating an uncalibrated, normalized, root-mean-squared (RMS) plot for each half-hour period. No plots were made between 02:30-04:10 and 08:10-08:40 due to a problem with the routine used to convert the raw data into files for processing. The following procedure was used to create each half-hour plot:

1. A five minute block of raw data was read from tape and converted to simple-input-output (SIO) format on disk, the first 64 channels were saved, and the RMS amplitude was calculated using an averaging period of 1 second (250 samples). This procedure was repeated for six consecutive 5-min blocks of data.
2. The six time-averaged files were then concatenated to form one 30-minute file.
3. Each channel of the 30-minute file was normalized by its largest value and then plotted, 64 channels per page.

The correspondence between the channel numbers and the positions of the hydrophones of the vertical array can be found from Figure II.1. Although this correspondence was assumed throughout the processing of the data and is believed to be correct, the possiblility that the channels within each of the proces-

sors of the vertical array are reversed has not been completely eliminated. The OBS channel-component correspondence can be found in Table 4.

TABLE 4

Channel and Proc No.	Component	Channel and Proc No.
1 (proc 3e)	vertical	9 (proc 23)
2 (proc 3e)	longitudinal	10 (proc 23)
3 (proc 3e)	transverse	11 (proc 23)
4 (proc 3e)	hydrophone	12 (proc 23)
5 (proc 3e)	vertical	13 (proc 23)
6 (proc 3e)	longitudinal	14 (proc 23)
7 (proc 3e)	transverse	15 (proc 23)
8 (proc 3e)	hydrophone	16 (proc 23)

Figures VI.A.1 through VI.A.15 contain the 30-minute RMS plots for the first 64 channels. In several instances, jumps in the RMS levels can be attributed to changes in the array variable gain. For example, at the beginning of tape 7, between records 1 and 1058 (Figure VI.A.1), the step increase in the RMS levels can be correlated with a change in the variable gain at this time (see Table 2 - Table of Gains, tape 7, ~02:01). Similarly, the large swings in the RMS levels between records 46440 and 47497 (Figure VI.A.5) and between records 109860 and 110917 (Figure VI.A.14) appear to be caused by changes in the array variable gain (see Table 2, tape 7, ~05:42 and ~10:41, respectively). Interesting signals of unknown origin between records 70,000 and 110,000 are investigated further in Section C.

B. Auto-Spectral Plots

In Figures VI.B.1 through VI.B.12, auto-spectral estimates from the bottom 36 hydrophones of the vertical array are plotted at times chosen to give representative frequency spectra, both in the presence and absence of ships as recorded in the log. The channel number for each autospectral plot is given in the lower left-hand corner of the plot. A first glance at the auto-spectral plots reveals that the spectral levels of channels 54 (Figure VI.B.1) and 23 (Figure VI.B.3) are consistently about 5 dB and 10 dB, respectively, below those of the other vertical array hydrophone channels. Also, channels 36, 41, 44, 45, 46, 48, 49, 50, 51, and 52 contain a signal centered at 6 to 7 Hz that may be strum related. In addition, all channels contain a peak at 120 Hz that typically extends around 10 dB above the background noise at neighboring frequencies and is attributed to electrical contamination from FLIP. Figures VI.B.1 - VI.B.3 are plots of the auto-spectra during a time when no passing ships were reported in the log. They agree reasonably well with estimates of predicted ambient noise spectra for the northeast Pacific in areas of moderate to heavy shipping [1]. The auto-spectral levels of Figures VI.B.4 - VI.B.6 are from a time when a passing ship was reported in the log (Ship 4, Figure V.3). They contain an 8 Hz fundamental frequency and associated harmonics. Figures VI.B.7 - VI.B.9 are also auto-spectral plots from a time when no ships were reported in the log. However, note the strong peaks near 18 Hz. This 18-Hz energy is perhaps indicative of the presence of whales [2]. Figures VI.B.10 - VI.B.12 are auto-spectral levels from tape 3 and offer another example of ship-generated tonals of a 5 Hz fundamental frequency (Ship 1, Figure V.1).

C. Large Amplitude Signals

Some large amplitude signals of unknown origin are revealed in the 30-minute RMS time series plots, as mentioned previously. Figures VI.C.1 - VI.C.12 are plots of normalized, desampled time series that show these signals in greater detail. Figures VI.C.1 - VI.C.4 cover a time period of 2 min, 22 sec; the remaining time series span a period of slightly over 4 min, 15 sec. The desampling factor is five, i.e., only every fifth data point is plotted. Most of the signals actually appear to be doublets on the two horizontal geophone components as well as on the OBS hydrophones. However, the first "arrival", or the singlet which appears first in time, does not appear on the OBS hydrophones, nor on the vertical line array hydrophones. This is especially evident in Figure VI.C.11 which is a plot of the desampled time series for each channel of the four OBS's. (The OBS channel-component correspondence can be found in Table 4).

The onset times and durations of the second "arrivals" occurring between records 27,414 and 122,543 are listed in Table 5.

TABLE 5		
Approximate Start Record	Approximate Start Time	Duration (seconds)
71125	07:36, 9 Oct	22
73100	07:46, 9 Oct	20
91200	09:11, 9 Oct	21
95800	09:32, 9 Oct	20
109000	10:34, 9 Oct	56

1. Spectral Ratios

Estimates of the auto-spectra made during the occurrence of the unknown arrivals were divided by estimates made before the arrivals (i.e., dB values were subtracted) to yield spectral ratios for each hydrophone of the vertical line array. Figures VI.C1.1 - VI.C1.9 are plots of spectral ratios for the first three pairs of arrivals listed in Table 5. These plots show that the preponderance of the signal energy is located between 8 and 30 Hz, with maximum energy near 10 Hz.

2. Coherence

A measure of the linear relatedness between the data recorded by two elements in the frequency domain is given by the complex coherence function. The magnitude of the coherence function is defined as the magnitude of the cross-spectral estimate divided by the geometric mean of the individual channel auto-spectral estimates [3]:

$$|\gamma(f)| \equiv \frac{|G_{xy}(f)|}{G_{xx}(f)\cdot G_{yy}(f)^{1/2}}$$

The complex coherence phase is given by [3]:

$$\theta_{xy}(f) \equiv arctan\left[\frac{Q_{xy}(f)}{C_{xy}(f)}\right], \quad \text{where} \quad G_{xy}(f) \equiv C_{xy}(f) - iQ_{xy}(f)$$

For frequencies corresponding to an appreciable coherence amplitude, the slope of the complex coherence phase plotted against frequency is proportional to the time delay between two spatially separated elements:

$$\theta_{xy}(f) = 2\pi f \tau_0, \quad \text{where} \quad \tau_0 \equiv \text{time delay}$$

Therefore, the coherence function potentially provides a means of determining if a given signal is acoustic or some form of noise (i.e., electrical noise or mechanical array strum), since an acoustic signal cannot propagate across the array slower than the speed of sound in water.

Figures VI.C2.1 - VI.C2.7 are plots of the coherence magnitude (in the left-hand plots), as well as the complex coherence phase (in the right-hand plots), for different hydrophone pairs. The dashed lines in the figures are estimates of the level below which 95 percent of the coherence magnitude estimates should fall given that the two input time series are uncorrelated. They were determined by plotting $|\gamma(f)|$ between two random, uncorrelated Gaussian distributions, using the same procedure as was used to process the actual data (see Figure VI.C.2.8) and noting the amplitude level below which 95 percent of the samples fell. Values of the coherence function magnitude above the dashed lines are considered to be an indication of cross-channel coherence at a particular frequency.

Figures VI.C2.1 - VI.C2.3 are plots of the coherence between the OBS hydrophones (channels 4, 8, 12, and 16). The "arrivals" begin near sample 24,500 in the record, which is where the coherence becomes significant for frequencies between about 5 and 40 Hz. The time delay calculated from the slope of the complex coherence phase versus frequency between the two hydrophones associated with OBS processor 3e (Figure VI.C2.1) is approximately 22 msec. Assuming a signal propagating horizontally at a speed of 1500 m/sec, this time delay implies an effective OBS unit separation of around 33 m. Since the effective OBS separation must lie between 0 and 75 m for an acoustic signal, then this estimate is certainly consistent with the assumption. However, until the positions of the OBS's are determined from the navigation data, a more definitive verification of the nature of the signals cannot be made.

Figures VI.C2.4 - VI.C2.7 are plots of the coherence between different hydrophones of the vertical line array at the same times as in Figures VI.C2.1 - VI.C2.3. The interpretation of the plots is difficult due to the high coherence of ambient noise below around 10 Hz at all times. Even so, as can be seen from Figure VI.C2.4, the dip in the amplitude at around 8 Hz is missing only during the time of the arrival (samples 24,577 to 32,768 of record 72,744). The phase of the coherence function is nearly 180 degrees at zero frequency in Figure VI.C2.4, indicating that the polarity of the wiring of one channel is reversed with respect to the other. After reversing the polarity of one of the channels, the time delay is nearly zero, in agreement with a horizontally propagating signal.

Therefore, both the coherence between the OBS hydrophones and between the vertical line array hydrophones are consistent with a horizontally propagating acoustic wave.

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APPENDIX - VERTICAL LINE ARRAY HYDROPHONE CALIBRATION CURVE

A block diagram of the vertical line array electronic data acquisition electronics is presented in Figure A.1 (located at the end of the figures). It indicates that the hydrophone sensitivity is - 193 dB re 1 V/μPa, that the total fixed gain of + 46 dB is due to the hydrophone preamp and the differential-to-single line driver, that the variable gain can be adjusted from 14 to 60 dB, and that the A/D converter tolerates a maximum ±10 V input before clipping, in addition to providing a 12-bit output. It also shows a rough plot of the response of the system's band pass filter. A more detailed plot of this filter's response, from 0 to 250 Hz, is shown in the upper panel of Figure A.2. This plot was obtained from measurements made in the laboratory. The lower panel of Figure A.2 presents the total calibration curve, including variable and fixed gains, that is used to properly calibrate the vertical line array auto-spectra presented in Section VI.B.

The array is divided into 8-channel sections. Associated with each section is a processor that controls the sampling and formatting of the data from the 8 channels within that section. Since the A/D converter in each of the processors does not contain a sample-and-hold circuit, then the data from the 8 channels are sampled at slightly different times. These time delays must be taken into account in coherent processing at the higher frequencies. The lowermost element of each section is sampled first, followed by the next deepest, and so on, until the shallowest element of the section is sampled. The sampling frequency of the array is 250 Hz, i.e., consecutive samples from a given element are separated by 4 msec. Therefore, the time delay between samples from two adjacent channels within a given section is 0.5 ms (= 4 msec/8 channels). For example, a sample from the uppermost element in a section is obtained 3.5 msec (= 0.5 msec x 7) after the sample from the lowermost element in the section. This time delay represents a phase shift of 12.6° at 10 Hz (= 3.5 msec x 10 Hz x 360°).

References

[1] R. Urick, Principles of Underwater Sound, 3rd ed., McGraw-Hill, Inc. (1983).

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[3] J. S. Bendat and A. G. Piersol, Random Data: Analysis and Measurement Procedures, 2nd ed., John Wiley and Sons (1986).

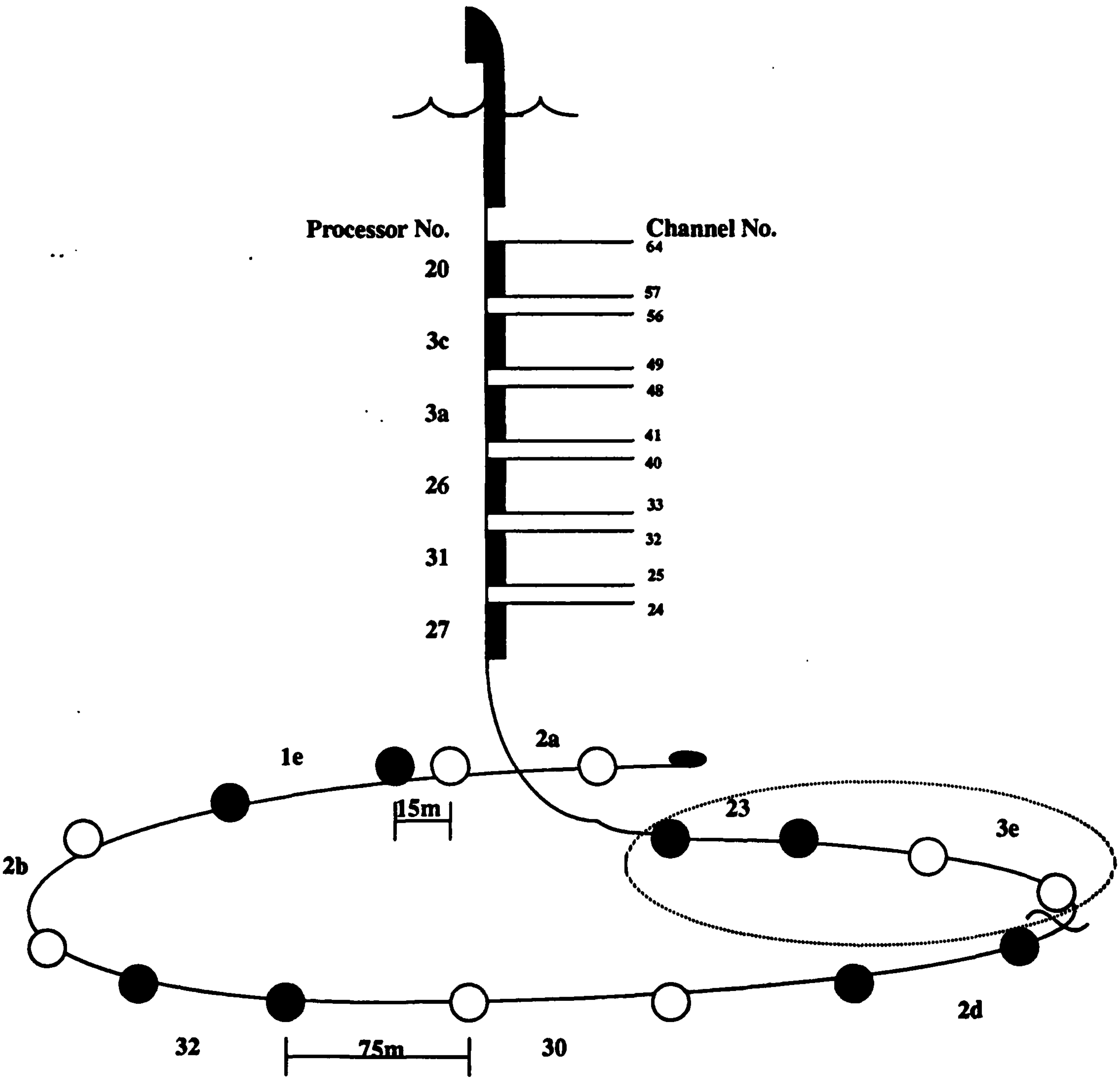

Processor No.
Channel No.
64
20
57
56
3c
49
48
3a
41
40
26
33
32
31
25
24
27
1e
2a
15m
23
3e
2b
2d
32
75m
30

Figure II.1

Figure III.1

FLIP TAPE LOG SUMMARY

The following are the salient entries from the tape log kept aboard FLIP. All times are reported in Greenwich Mean Time. To obtain local time, subtract 7 hours.

5 October 1991 (JD 278)

20:45:30	Begin Tape 1 , Gain = 12 Deploying Array

6 October 1991 (JD 279)

	Deploying Array
07:21	Tape 2 started

7 October 1991 (JD 280)

02:37	Tape 2 collecting data Adjusting/Calibrating Array
07:11:30	Proc Gain = 160
07:36:05	Tape 3 started
08:40	Proc 8A not on seafloor->pay out winch
08:55	Gain = 160 Array collecting data
>12:00-14:00	Ship 1
>15:00-16:00+	Ship 2 <- From second log book
16:27:19	Tape 4 started Array calibrated/adjusted
18:35-36	8A Ball being tugged by tether
19:09:00	Gain = 120 Make ship going by
19:51	Take in 50m of wire to get tether off bottom
19:52	Large amplitude signals in 6A & 6B ->Pulled tether across balls?
>19:09-21:00+	Ship 3
20:20	Ship 3 on radar at 21.2 nmiles,279 deg.
20:28	Gain = 100
20:24	Ship 3 at 20.1 nm,273.5 deg. true (Heading 165 deg.,15 knots)
20:30:45	Gain = 80
20:32:45	Gain = 60
20:47	Ship 3 at 18.5 nm, 261 deg. true
	Array adjusted/reset to remove large amp sigs
21:13	Ship 3 at 18.3 nm, 243.5 deg
21:24:11	Start tape 5
	Still have large amp sigs on 8A-> pay out to 2285 m.
22:51	Gain = 120
22:54	Ball 8B still being pulled by tether,esp. in ver+cross axes Readjust array/FLIP mooring position

8 October 1991 (JD 281)

00:15:31	Tape 5 end
00:23:01	Tape 6 started
00:53:30	Lost Data Resync
>01:00-03:00	Ship 4
01:07:21	Lost Data Ship passing by
01:14:00	Gain = 12
01:23:00	Power off
02:05	Tape 7 started Gain = 120
03:15	Reset all processors
03:40	Gain = 120
05:43	Gain = 160
10:41	Gain = 80
10:42	Gain = 120 Downward propagating energy on VAST array but no obvious ship nearby
11:56	End tape 7 start tape 8
12:24:30	Large amplitude signals throughout
12:26:10	Gain = 100
12:26:30	Gain = 120
13:15:40	Gain = 100
13:37-15:00+	Ship 5
13:37	Ship 5 190 degs. @ 14 knots 10.5 nm heading 048 deg true heading North 8.9 nm 058
14:12	Glitches, Lost Data
14:23:30	Gain = 100
14:12 ??	Ship 5 bearing 094, range 6.8 nm

Figure III.1a

14:26	Many glitches
14:31	Ship bearing 125 deg,range 7.7 nm
14:59	Array Glitches
15:25	Whole array collect data except 4 Many glitches
15:47:00	Cycle power
16:01	Winch coming up ~7m/m (min?)
16:40	End tape 8 Array Off
17:00-03:00	Recover Array

Figure III.1b

TABLE 2

TABLE of GAINS

TAPE	JD	TIME	REC NO	GAIN
3	280	07:36	1	5
	280	08:30:22.038	11471	60
	280	08:30:31.409	11504	160
	280	08:47:46.155	15148	240
	280	08:55:31.280	16786	160
	280	08:58:38.125	17444	5
	280	09:35:13.696	25176	160
	280	12:17:22.981	59439	120
4	280	16:27	1	0
	280	16:30:59.816	677	160
	280	16:31:11.458	718	5
	280	16:55:08.591	5747	120
	280	17:09:29.271	8778	160
	280	19:09:00.369	34032	120
	280	20:28:14.12	50773	100
	280	20:30:35.254	51270	80
	280	20:32:43.319	51721	60
5	280	21:24:10.979	1	60
	280	21:52:33.313	5996	5
	280	22:48:34.534	17833	60
	280	22:49:02.079	17930	160
	280	22:49:23.943	18007	120
6	281	00:23:13.564	1	0
	281	01:13:50.505	10696	60
	281	01:14:02.999	10740	5
	281	01:14:10.666	10767	12
	281	01:53:26.98	17160	80
7	281	02:00:14.751	1	80
	281	02:01:59.531	370	100
	281	02:04:02.486	803	120
	281	03:36:34.449	20355	25
	281	03:36:55.178	20428	5
	281	03:37:20.450	20517	12
	281	03:38:00.204	20657	160
	281	03:39:01.256	20872	120
	281	04:09:42.729	27357	5
	281	04:09:46.420	27370	120
	281	05:41:49.137	46819	160
	281	05:42:34.571	46979	240
	281	05:43:22.844	47149	5
	281	05:43:42.721	47219	160
	281	10:37:34.015	109310	80
	281	10:41:31.121	110145	5
	281	10:42:04.060	110261	120
8	281	11:56:33.574	1	120
	281	12:23:45.770	5749	100
	281	12:23:52.017	5771	80
	281	12:24:02.240	5807	60
	281	12:24:07.635	5826	50
	281	12:26:10.589	6259	100
	281	12:26:32.170	6335	120
	281	12:58:00.213	12984	50
	281	12:58:17.819	13046	5
	281	12:58:24.918	13071	8
	281	12:58:51.326	13164	25
	281	13:00:40.082	13547	50
	281	13:00:53.144	13593	60
	281	13:01:01.663	13623	80
	281	13:01:11.318	13657	100
	281	13:13:34.722	16275	50
	281	13:15:42.788	16726	100
	281	14:23:00.400	30945	60
	281	14:23:07.783	30971	100
	281	5:24:26.569	43788	60
	281	15:25:37.275	44037	100
	281	15:34:41.910	45955	120

Table 2

TABLE 3

```
1.) Tape 3 (109975 records)

        RECNO 4142 280 07:55:40.902
        diff= 283
        RECNO 4143  80 07:55:41.186      <=== Lost hundreds place in the day
        diff= -100130532
        RECNO 4144  80 07:55:41.470
        diff= 284
        .
        .
        RECNO 4354 280 07:56:41.102      <- Regained hundreds place
        diff= 100131100
        RECNO 4355 280 07:56:41.386
        diff= 284

2.) Tape 4 (62502 records)

        RECNO 5345 280 16:53:05.336
        diff= 284
        RECNO 5346 280 16:53:14.724      <=== Clock jumped forward
        diff= 9388
        RECNO 5347 280 16:53:15.008
        diff= 284
        **************************
        RECNO 19956 280 18:02:23.079
        diff= 0
        .                                <=== Clock not incrementing
        .
        RECNO 20863 280 18:02:23.079
        diff= 0
        RECNO 20864 280 18:06:41.198     <- Begin incrementing
        diff= 258119
        *****************************
        RECNO 24907 280 18:25:48.959
        diff= 0
        .                                <=== Clock not incrementing
        .
        RECNO 25300 280 18:25:48.959
        diff= 0
        RECNO 25301 280 18:27:41.123     <- Begin incrementing
        diff= 112164
        ****************************
        RECNO 56990 280 20:57:39.499
        diff= 284
        RECNO 56991 280 20:57:55.257     <=== Clock jumped forward
        diff= 15758
        RECNO 56992 280 20:57:55.541
        diff= 284
        ***************************
        RECNO 57082 280 20:58:21.097
        diff= 284
        RECNO 57083 280 20:58:31.922     <=== Clock jumped forward
        diff= 10825
        RECNO 57084 280 20:58:32.206
        diff= 284
```

```
3.) Tape 5 (36143 records)

        RECNO 3626 280 21:41:20.045
        diff= 0                          <=== Clock not incrementing
        .
        .
        RECNO 5389 280 21:41:20.045
        diff= 0
        RECNO 5390 280 21:49:41.232
        diff= 501187
        *****************************
        RECNO 15923 280 22:39:31.888
        diff= 0                          <=== Clock not incrementing
        .
        .
        RECNO 16271 280 22:39:31.888
        diff= 0
        RECNO 16272 280 22:41:11.274
        diff= 99386
        *****************************
        RECNO 22650 280 23:11:22.080
        diff= 0                          <=== Clock not incrementing
        .
        .
        RECNO 23032 280 23:11:22.080
        diff= 0
        RECNO 23033 280 23:13:11.120
        diff= 109040
        *****************************
        RECNO 33887 281 00:04:32.924
        diff= 0                          <=== Clock not incrementing
        .
        .
        RECNO 35076 281 00:04:32.924
        diff= 0
        RECNO 35077 281 00:10:11.118
        diff= 338194
        .
        .
        End of Tape

4.) Tape 6 (18562 records)

        RECNO 12653 281 01:23:05.928
        diff= 0                          <=== Clock not incrementing
        .
        .
        RECNO 12691 281 01:23:05.928
        diff= 0
        RECNO 12692 281 01:32:18.259
        diff= 552331

5.) Tape 7 (126000 records)

        RECNO 72313 281 07:42:28.099
        diff= 0                          <=== Clock not incrementing
        .
        .
        RECNO 80071 281 08:19:11.332
        diff= 2203233
        *****************************
        RECNO 80077 281 08:19:13.042     <- delta t>[.283-.285 seconds]
        diff= 290
        *****************************
```

Table 3

6.) Tape 8 (55263 records)

```
RECNO 10596 281 12:46:41.833
diff= 0                          <=== Clock not incrementing
.
.
RECNO 11860 281 12:46:41.833
diff= 0
RECNO 11861 281 12:52:41.324
diff= 359491
*****************************
RECNO 42784 281 15:19:14.798     <===Clock jumped
diff= 12893
*****************************
RECNO 42845 281 15:19:39.181     <===Clock jumped
diff= 7345
*****************************
RECNO 42903 281 15:20:03.533     <===Clock jumped
diff= 8167
*****************************
RECNO 42967 281 15:20:28.139     <===Clock jumped
diff= 6717
*****************************
RECNO 43076 281 15:21:04.391     <===Clock jumped
diff= 5585
*****************************
RECNO 44058 281 15:25:42.954
diff= 0                          <===Clock not incrementing
.
.
RECNO 45318 281 15:25:42.954
diff= 0
RECNO 45319 281 15:31:41.309
diff= 358355
*****************************
RECNO 48534 281 15:47:01.996     <===Clock jumped
diff= 8039
*****************************
RECNO 48600 281 15:47:20.738     <===Clock jumped
*****************************
RECNO 48995 281 15:49:19.222     <===Clock jumped
diff= 6605
*****************************
RECNO 49083 281 15:49:49.471     <===Clock jumped
diff= 5544
*****************************
RECNO 49160 281 15:50:16.916     <===Clock jumped
diff= 5864
*****************************
RECNO 49208 281 15:50:35.682     <===Clock jumped
diff= 5420
*****************************
RECNO 49633 281 15:52:46.191     <===Clock jumped
diff= 10110
*****************************
RECNO 49753 281 15:56:48.381     <===Clock jumped
diff= 208399
*****************************
RECNO 52355 281 16:11:55.511     <===Clock jumped
diff= 168553
*****************************
RECNO 55249 281 16:39:56.163     <===Clock jumped
diff= 859160
```

Sampling at 250 samples per second, and recording 71 samples/record, there are 71/250 or .284 seconds/record. The value of the GOES entry in the read from each record header and compared to the value in the previous record header. If the difference between the two was not between .283 and .285 seconds then the latter record number and the time difference were printed.

Many times the GOES clock entry stopped incrementing but in nearly every case, once it began incrementing again, it did so with the value one would expect by multiplying the number of records for which it did not increment times .284sec/rec and adding this to the last properly incremented value of the GOES entry (ie. the clock did not lose time). For example in Tape 7, the clock did not increment for records 72313 - 80070. 80071 - 72312 = 7759 records * .284 sec/record = 2203.556 seconds and 08:19:11.332 - 07:42:28.099 = 2203.517 seconds.

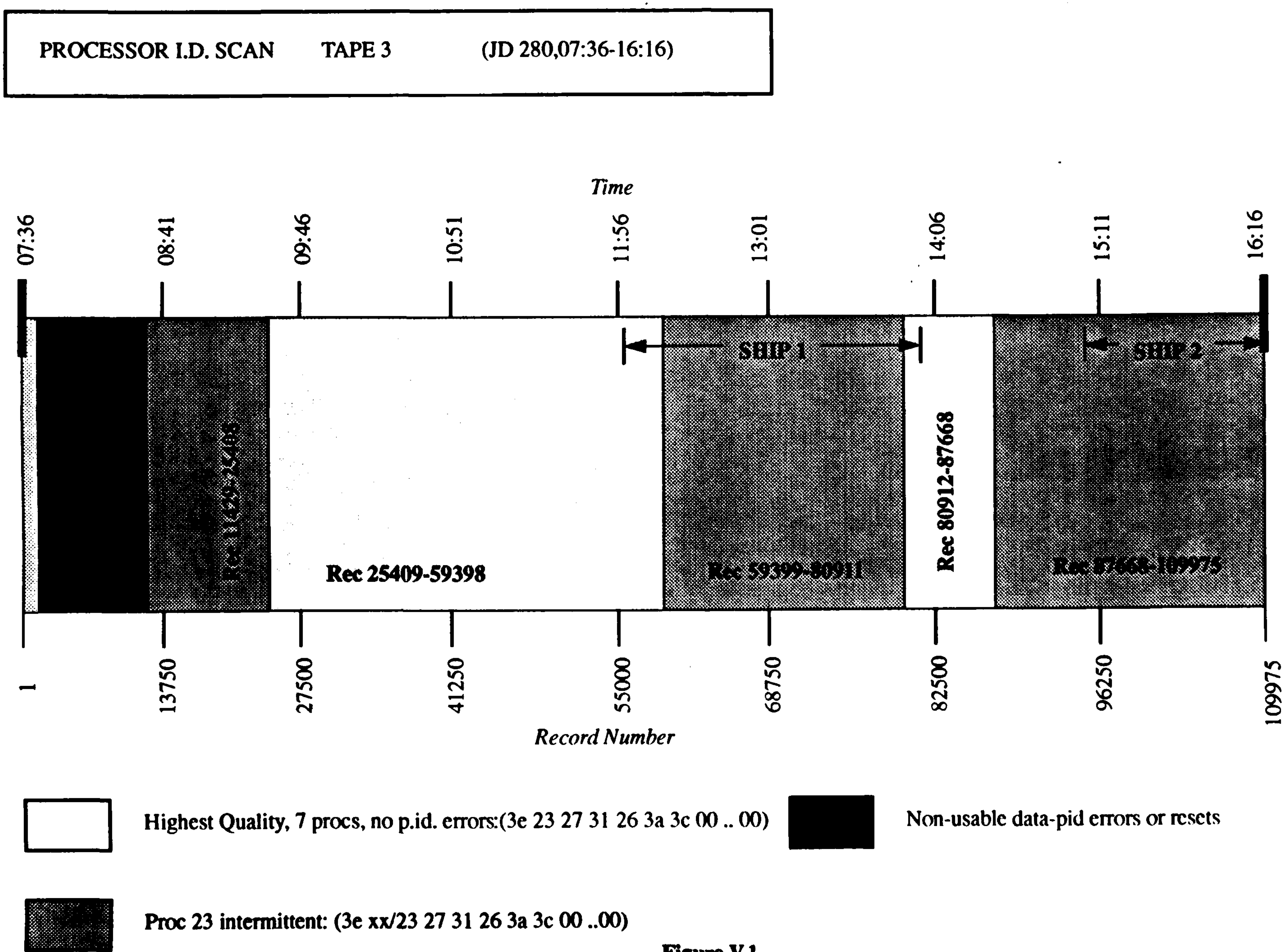
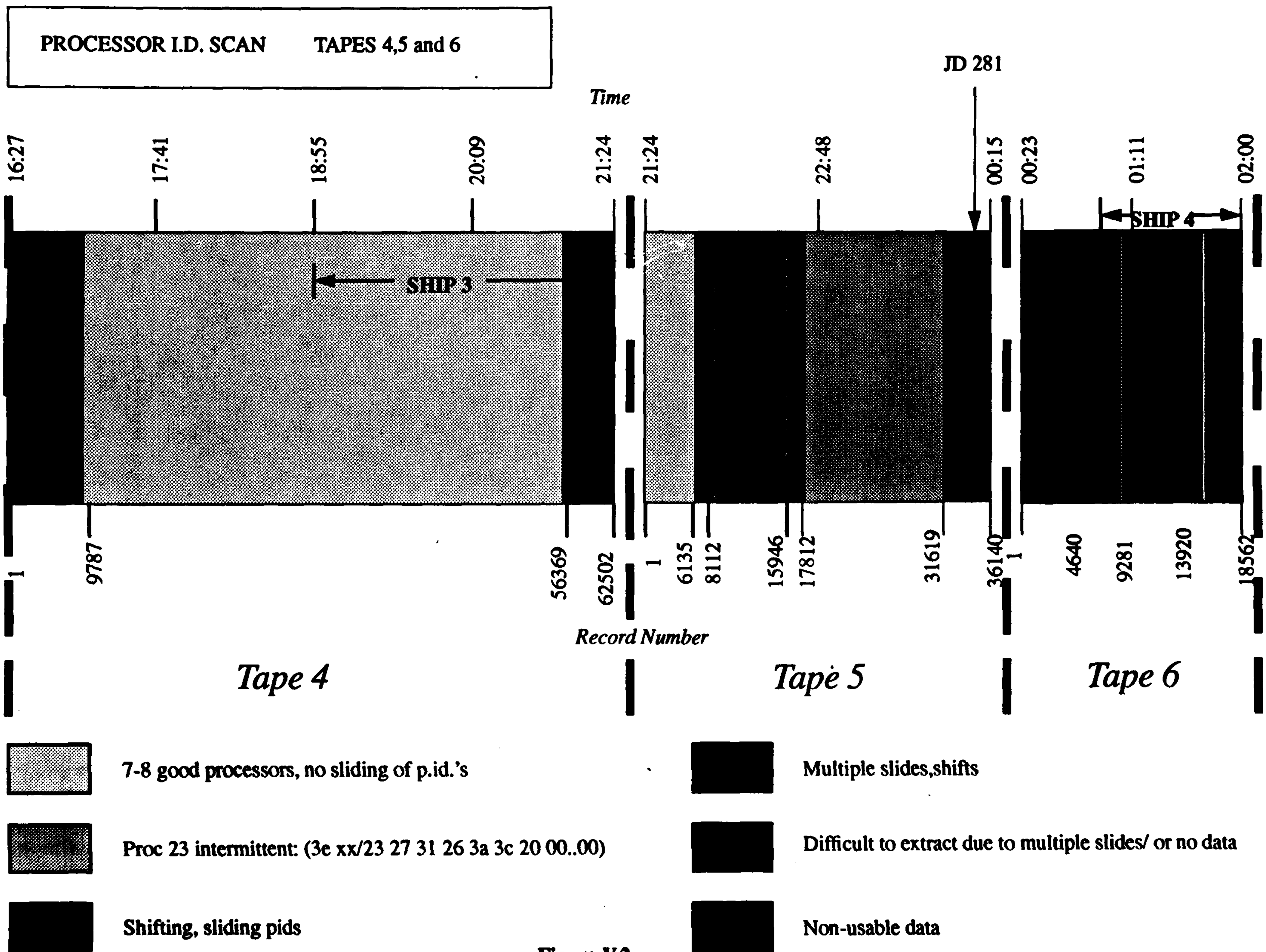

PROCESSOR I.D. SCAN
TAPE 3
(JD 280,07:36-16:16)
Time
07:36
08:41
09:46
10:51
11:56
13:01
14:06
15:11
16:16
SHIP 1
SHIP 2
Rec 25409-59398
Rec 59399-80911
Rec 80912-87668
Rec 87668-109975
1
13750
27500
41250
55000
68750
82500
96250
109975
Record Number
Highest Quality, 7 procs, no p.id. errors:(3e 23 27 31 26 3a 3c 00 .. 00)
Non-usable data-pid errors or resets
Proc 23 intermittent: (3e xx/23 27 31 26 3a 3c 00 ..00)

Figure V.1



PROCESSOR I.D. SCAN TAPES 4,5 and 6
JD 281
Time
16:27
17:41
18:55
20:09
21:24
21:24
22:48
00:15
00:23
01:11
02:00
SHIP 3
SHIP 4
1
9787
56369
62502
1
6135
8112
15946
17812
31619
36140
1
4640
9281
13920
18562
Record Number
Tape 4
Tape 5
Tape 6
7-8 good processors, no sliding of p.id.'s
Proc 23 intermittent: (3e xx/23 27 31 26 3a 3c 20 00..00)
Shifting, sliding pids
Multiple slides,shifts
Difficult to extract due to multiple slides/ or no data
Non-usable data

Figure V.2

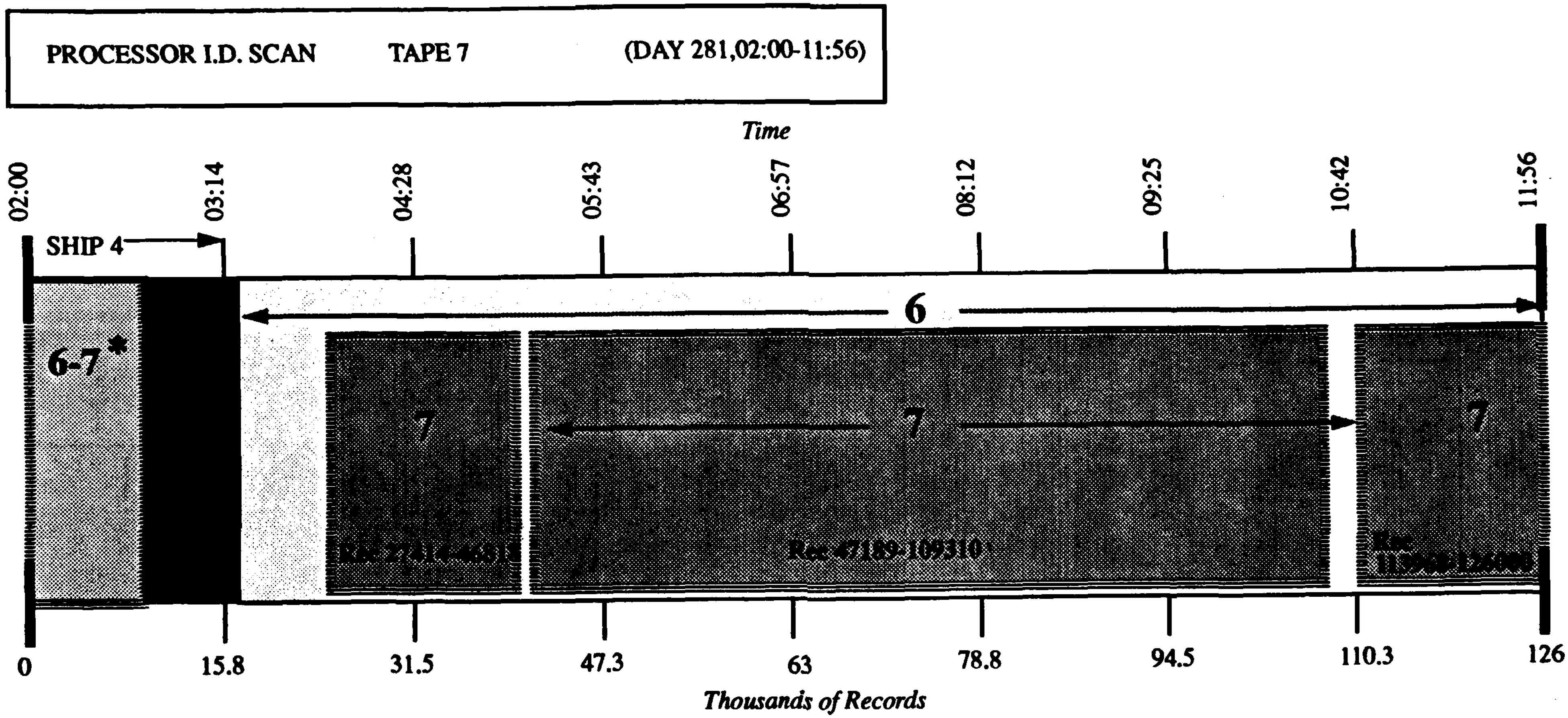


Figure V.3

* *6-7 Refers to the number of processors containing no processor i.d errors in the record headers*

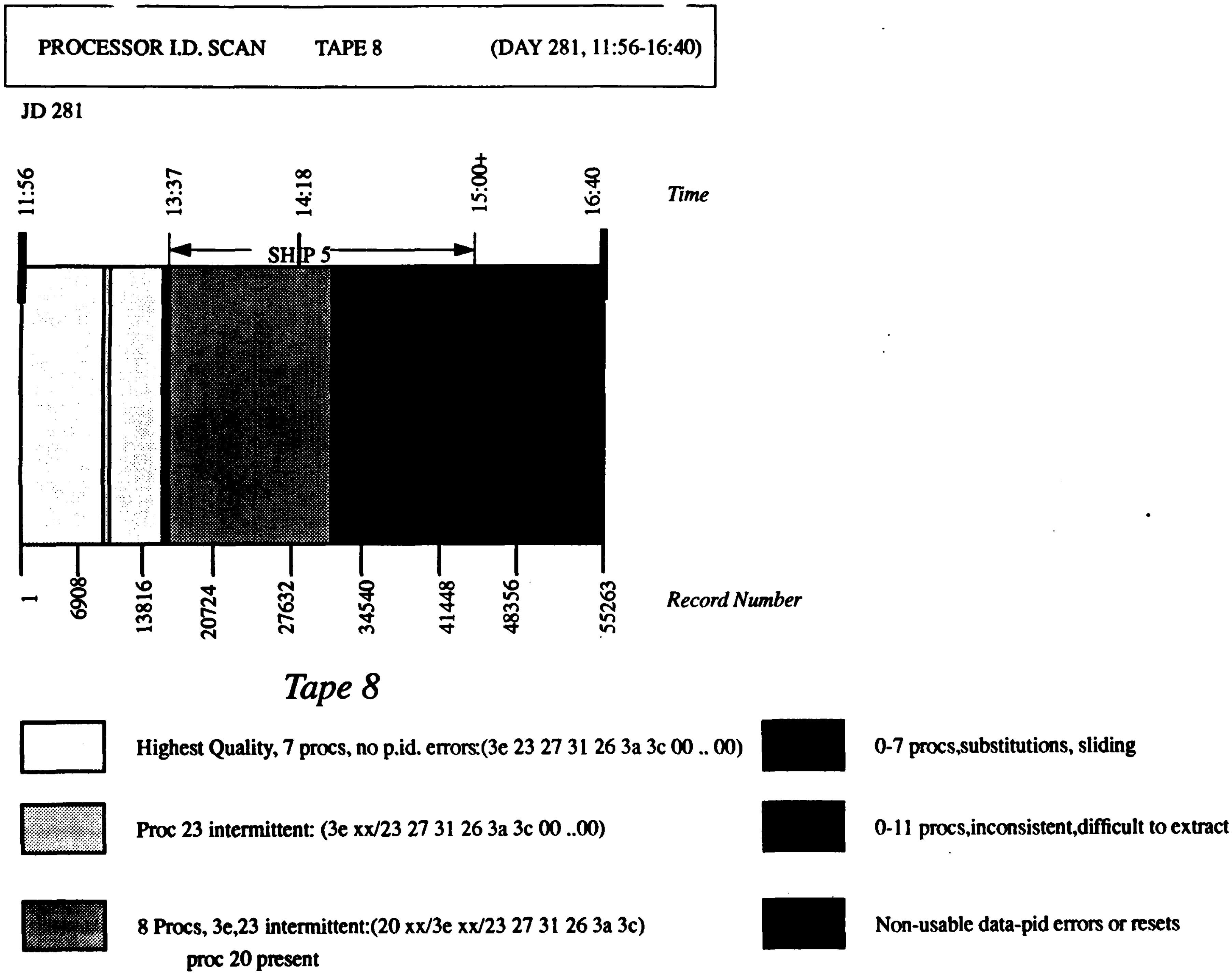

PROCESSOR I.D. SCAN
TAPE 8
(DAY 281, 11:56-16:40)
JD 281
11:56
13:37
14:18
15:00+
16:40
Time
SHIP 5
1
6908
13816
20724
27632
34540
41448
48356
55263
Record Number
Tape 8
Highest Quality, 7 procs, no p.id. errors:(3e 23 27 31 26 3a 3c 00 .. 00)
Proc 23 intermittent: (3e xx/23 27 31 26 3a 3c 00 ..00)
8 Procs, 3e,23 intermittent:(20 xx/3e xx/23 27 31 26 3a 3c)
proc 20 present
0-7 procs,substitutions, sliding
0-11 procs,inconsistent,difficult to extract
Non-usable data-pid errors or resets

Figure V.4

PROCESSOR I.D. SCAN TAPE 3 (DAY 280,07:36-16:16)

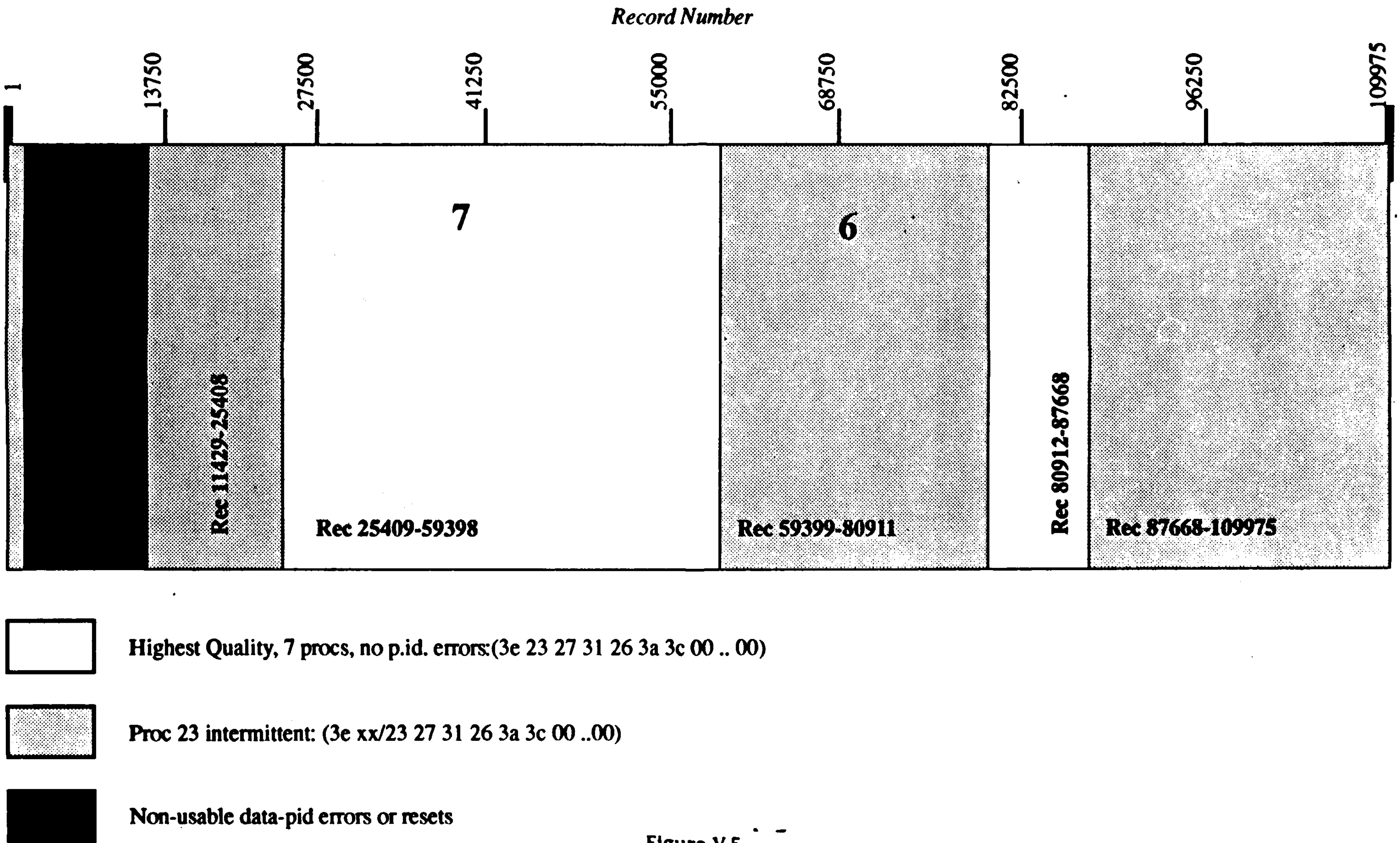


Figure V.5

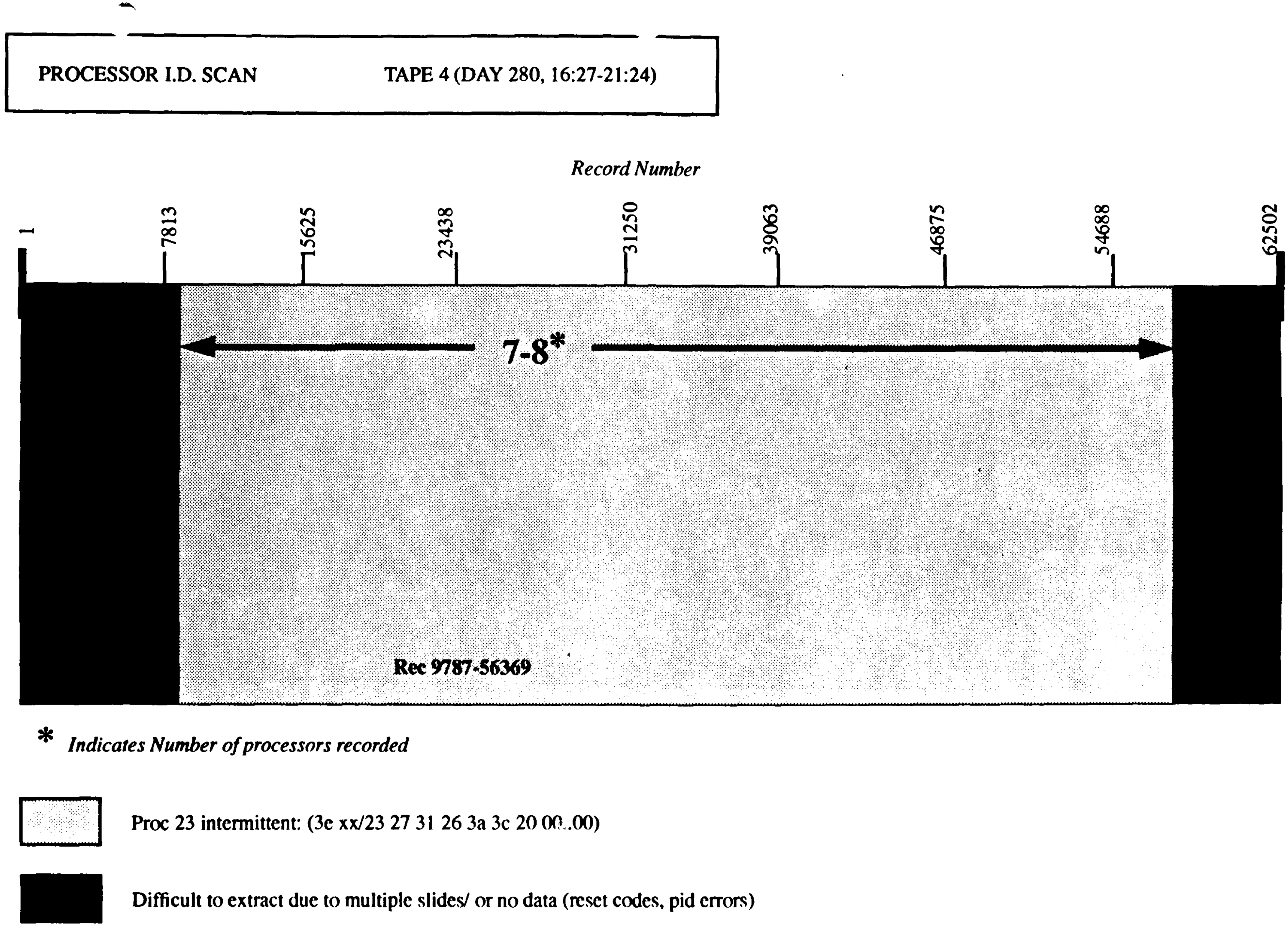

PROCESSOR I.D. SCAN
TAPE 4 (DAY 280, 16:27-21:24)
Record Number
1
7813
15625
23438
31250
39063
46875
54688
62502
7-8*
Rec 9787-56369
* Indicates Number of processors recorded
Proc 23 intermittent: (3e xx/23 27 31 26 3a 3c 20 00..00)
Difficult to extract due to multiple slides/ or no data (reset codes, pid errors)

Figure V.6

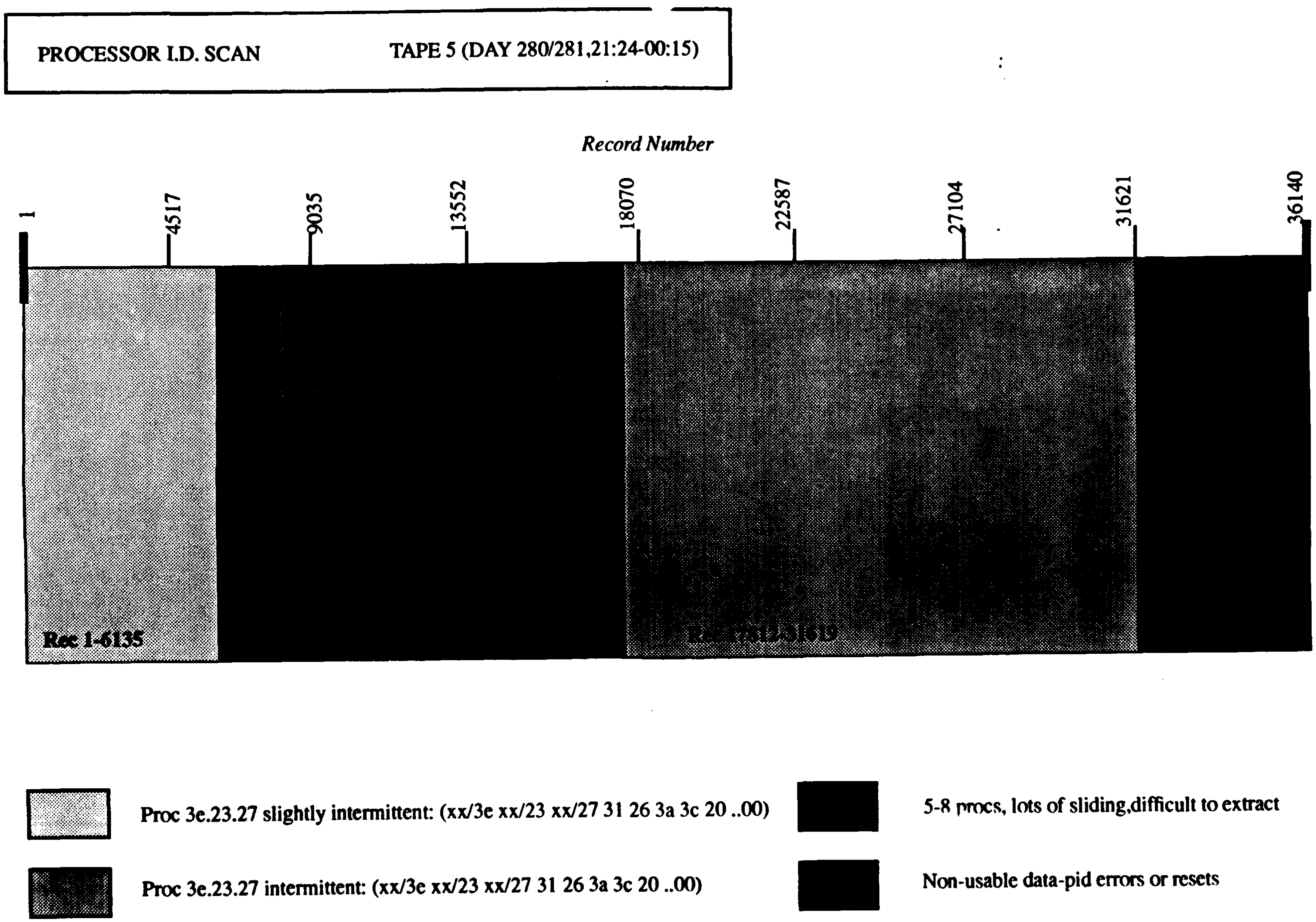
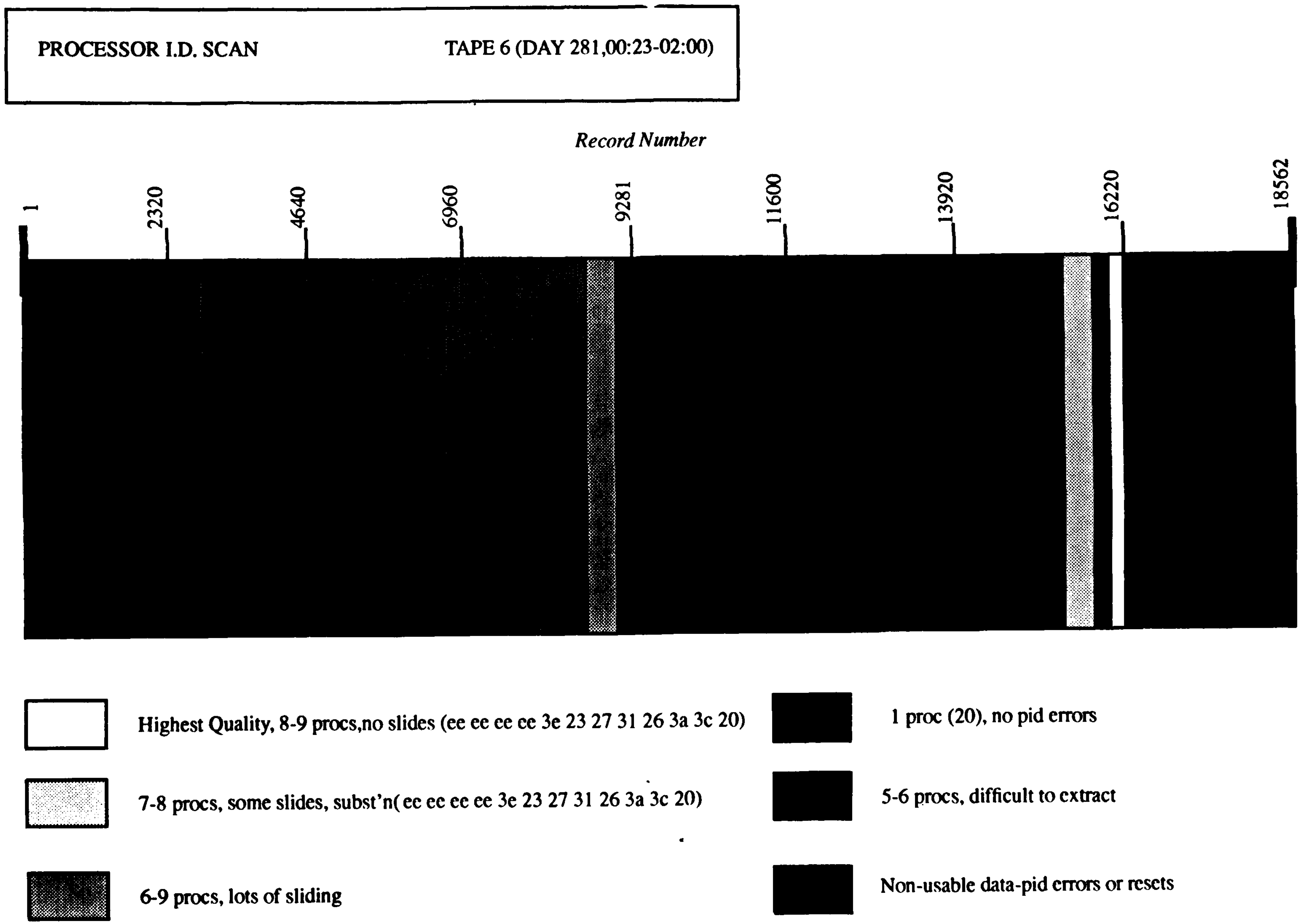
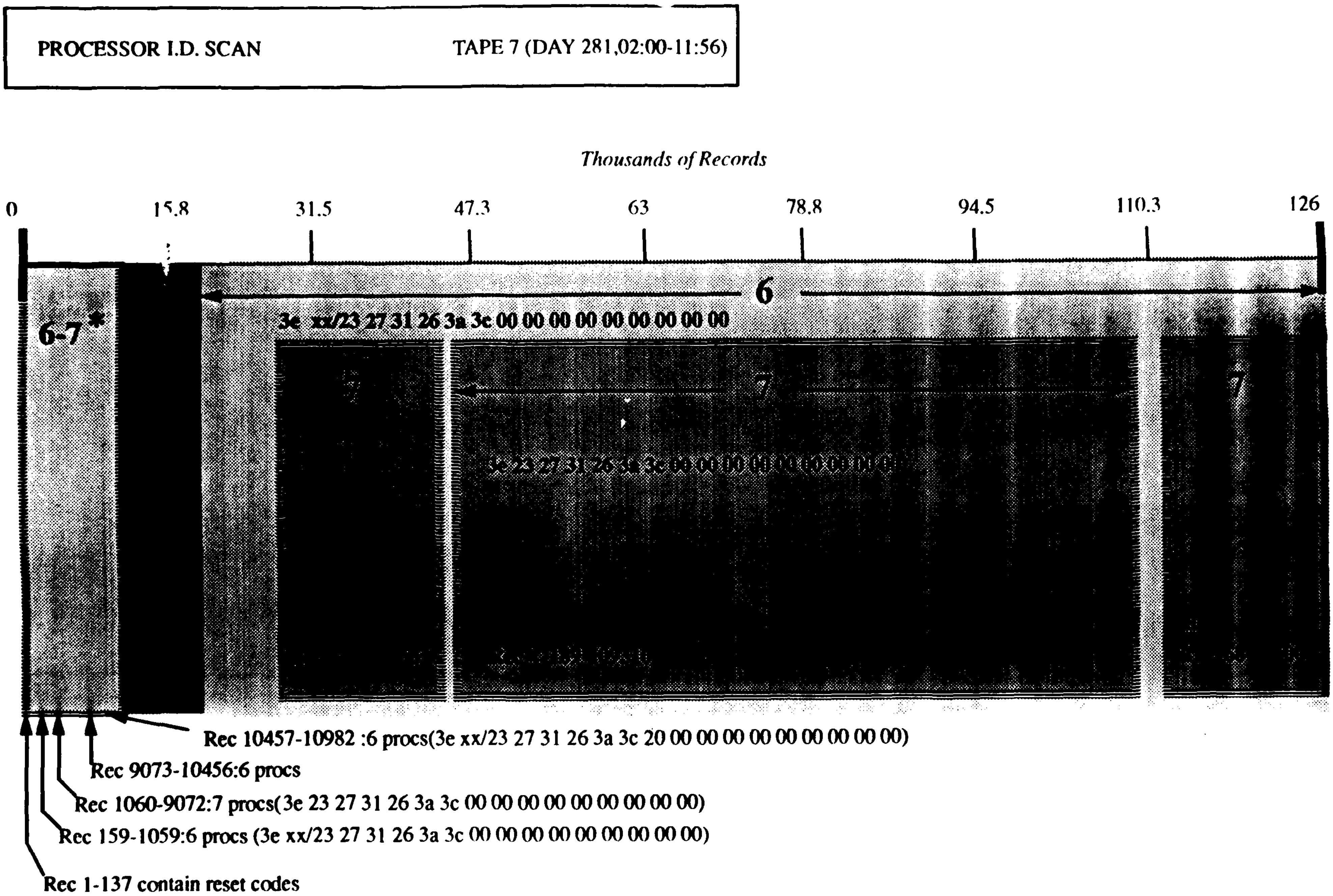

PROCESSOR I.D. SCAN
TAPE 5 (DAY 280/281,21:24-00:15)
Record Number
1
4517
9035
13552
18070
22587
27104
31621
36140
Rec 1-6135
Proc 3e.23.27 slightly intermittent: (xx/3e xx/23 xx/27 31 26 3a 3c 20 ..00)
Proc 3e.23.27 intermittent: (xx/3e xx/23 xx/27 31 26 3a 3c 20 ..00)
5-8 procs, lots of sliding,difficult to extract
Non-usable data-pid errors or resets

Figure V.7



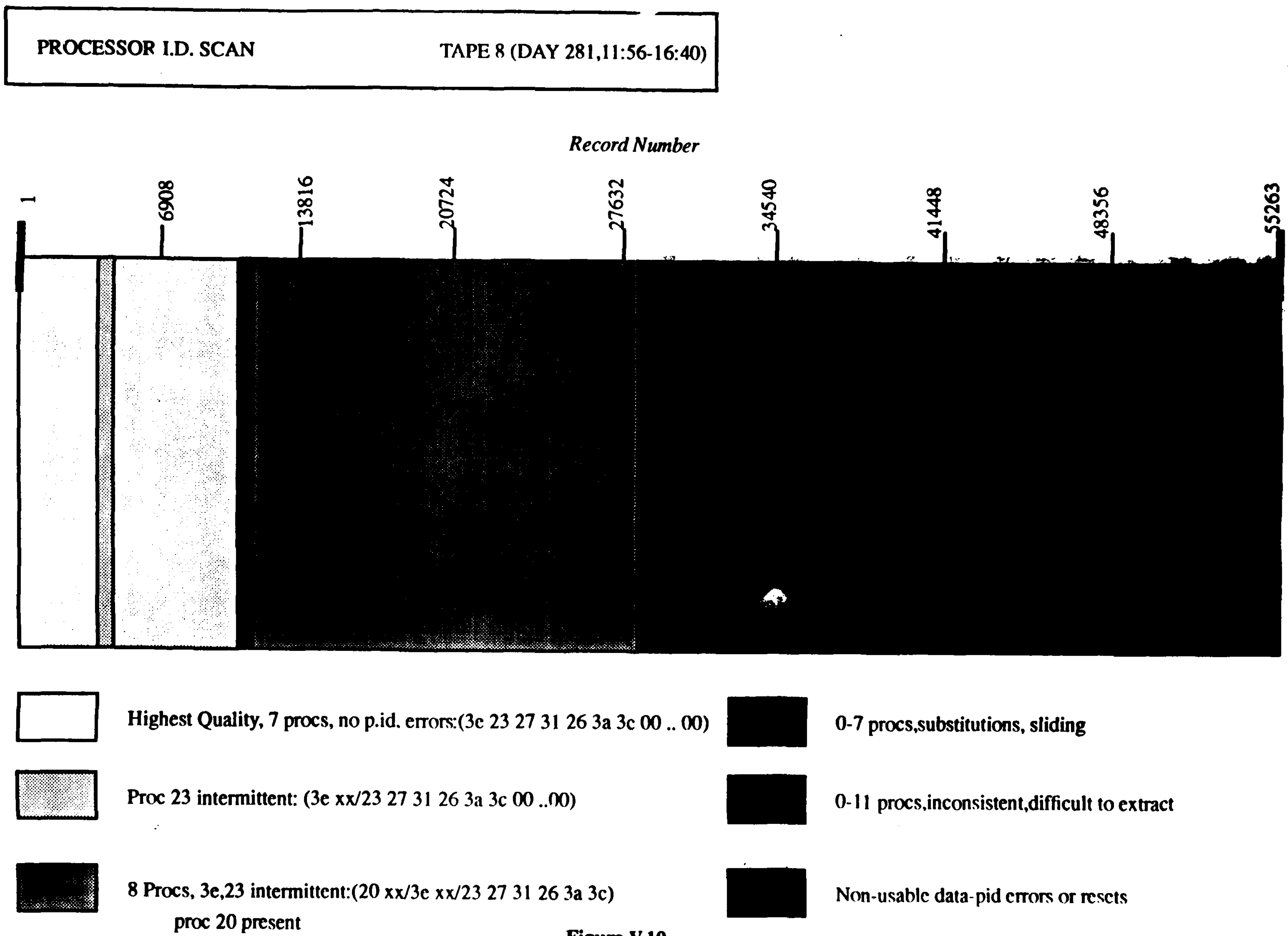
PROCESSOR I.D. SCAN
TAPE 6 (DAY 281,00:23-02:00)
Record Number
1
2320
4640
6960
9281
11600
13920
16220
18562
Highest Quality, 8-9 procs,no slides (ee ee ee ee 3e 23 27 31 26 3a 3c 20)
7-8 procs, some slides, subst'n(ee ee ee ee 3e 23 27 31 26 3a 3c 20)
6-9 procs, lots of sliding
1 proc (20), no pid errors
5-6 procs, difficult to extract
Non-usable data-pid errors or resets

Figure V.8



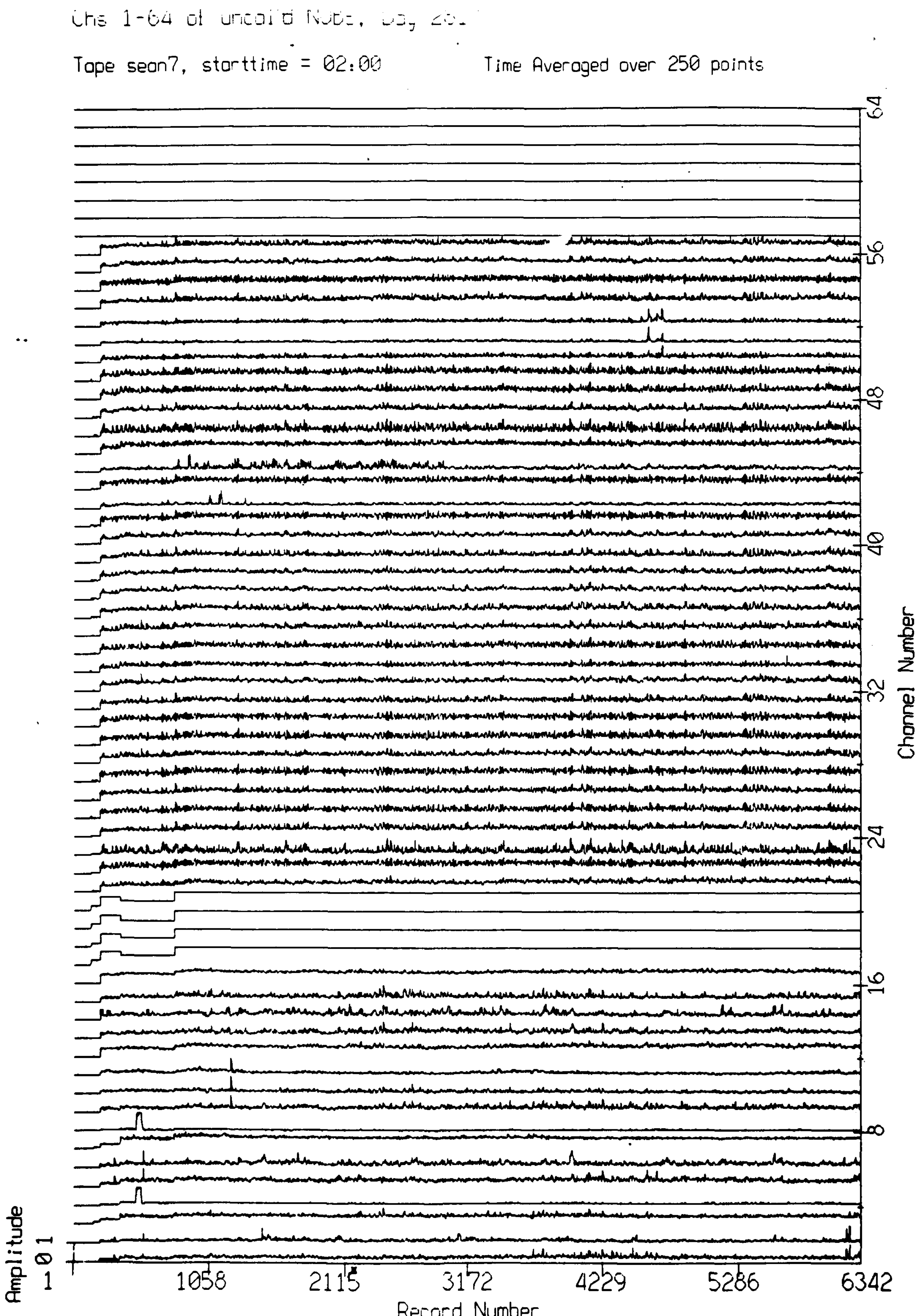
*6-7 Refers to the number of processors containing no processor i.d errors in the record headers

Figure V.9



PROCESSOR I.D. SCAN
TAPE 8 (DAY 281,11:56-16:40)
Record Number
1
6908
13816
20724
27632
34540
41448
48356
55263
Highest Quality, 7 procs, no p.id. errors:(3e 23 27 31 26 3a 3c 00 .. 00)
Proc 23 intermittent: (3e xx/23 27 31 26 3a 3c 00 ..00)
8 Procs, 3e,23 intermittent:(20 xx/3e xx/23 27 31 26 3a 3c)
proc 20 present
0-7 procs,substitutions, sliding
0-11 procs,inconsistent,difficult to extract
Non-usable data-pid errors or resets

Figure V.10



Chs 1-64 of
Tape sean7, starttime = 02:00
Time Averaged over 250 points
64
56
48
40
32
24
16
8
Channel Number
Amplitude
0 1
1
1058
2115
3172
4229
5286
6342
Record Number

Figure VI.A.1

Chs 1-64 of uncal'd N065, Day 281

Tape sean7, starttime = 04:09:58 Time Averaged over 250 points

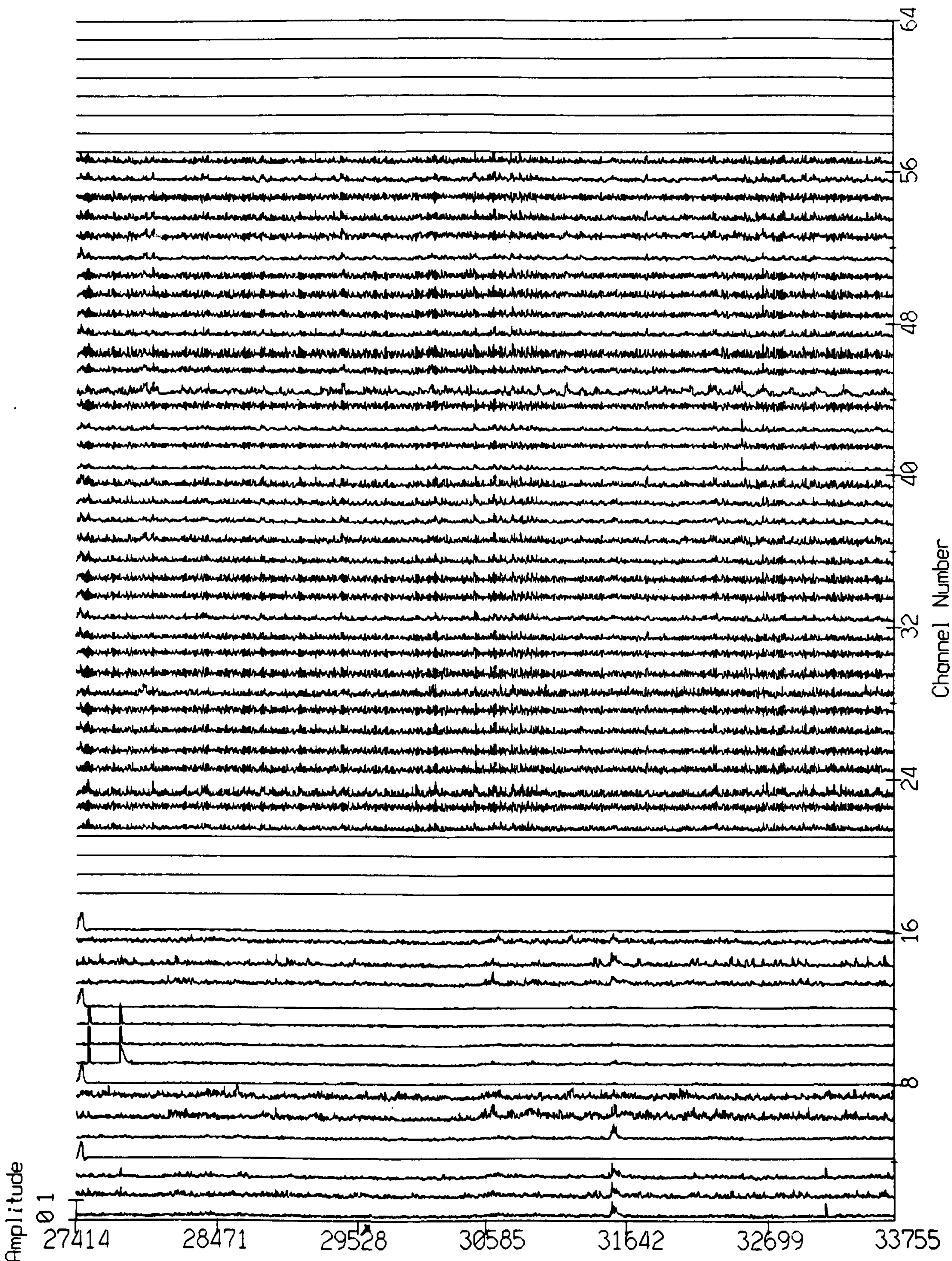
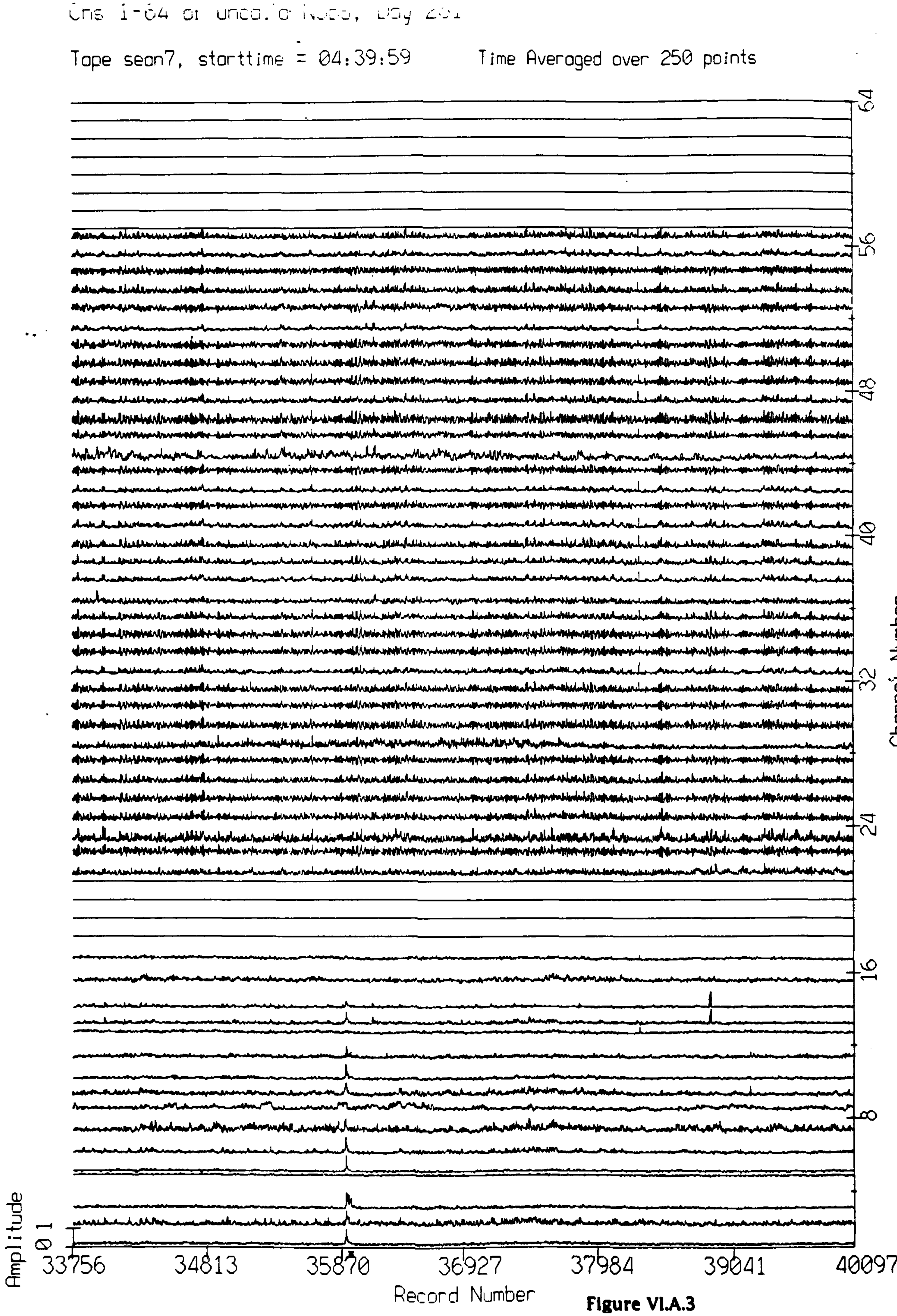


Figure VI.A.2



Chs 1-64 of uncal'd Noda, Day 201
Tape sean7, starttime = 04:39:59
Time Averaged over 250 points
64
56
48
40
32
24
16
8
Channel Number
Amplitude
0 1
33756
34813
35870
36927
37984
39041
40097
Record Number

Figure VI.A.3

Chs 1-64 of uncal'd [illegible], Day 201

Tape sean7, starttime = 05:10:00   Time Averaged over 250 points

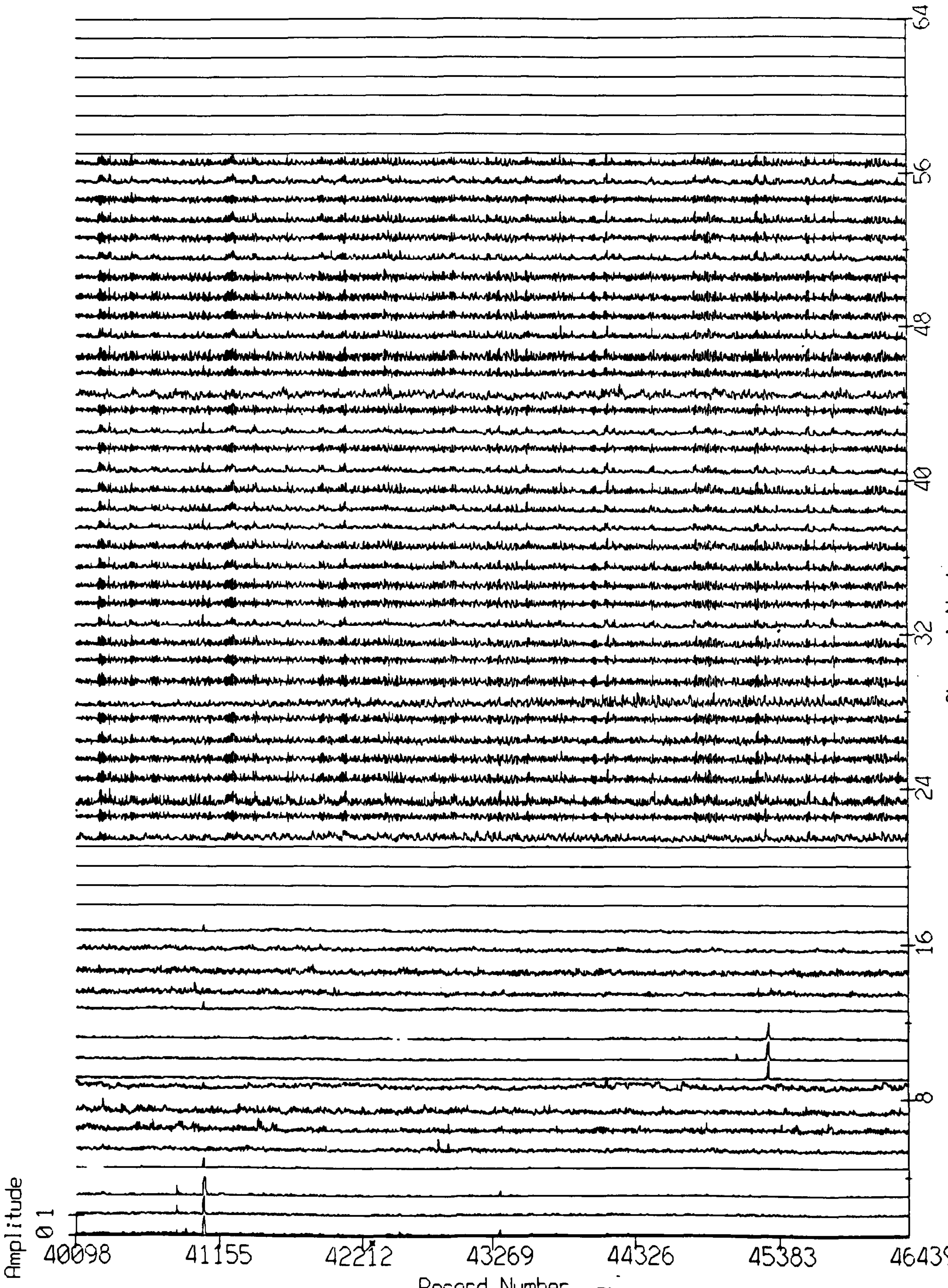
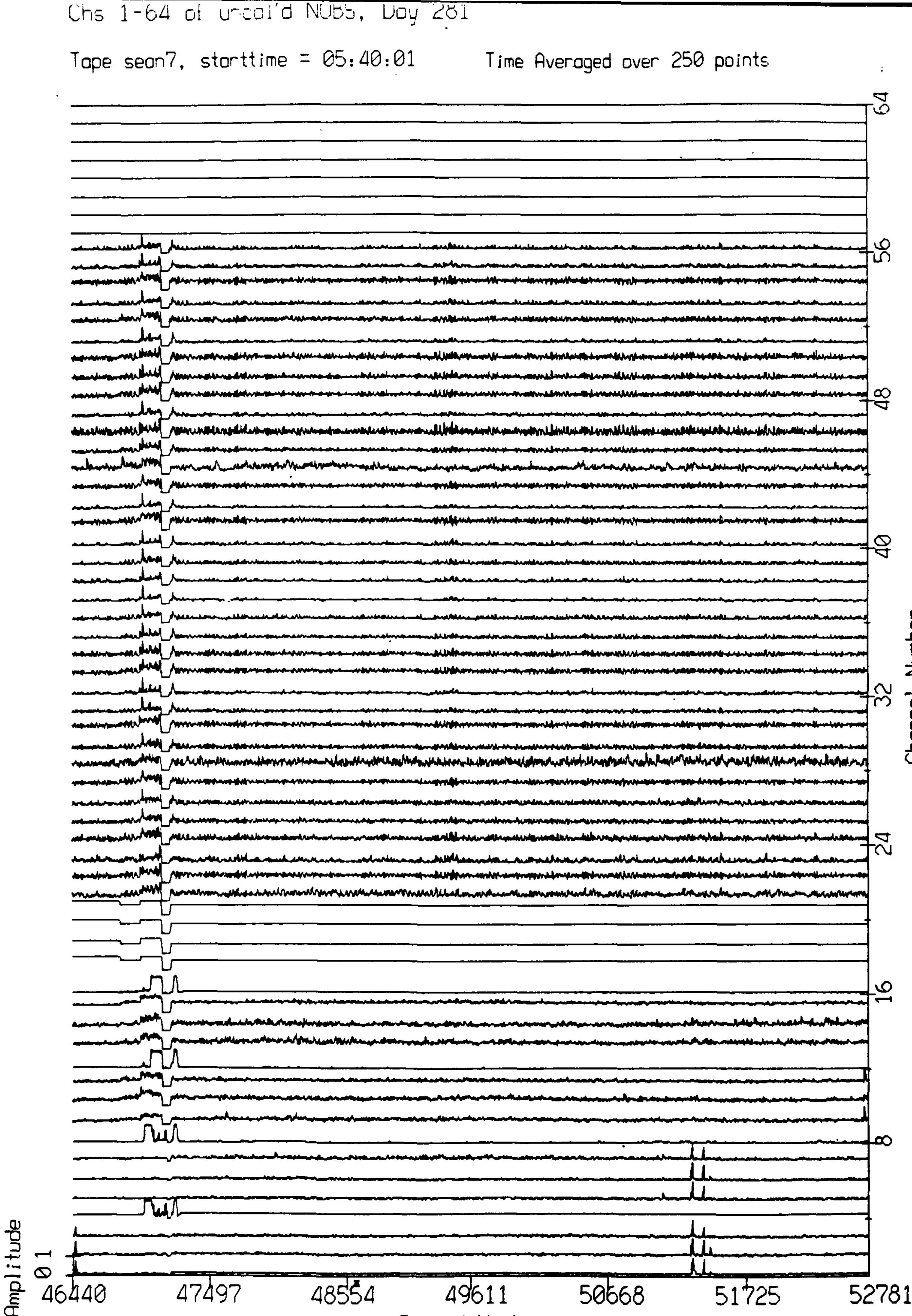
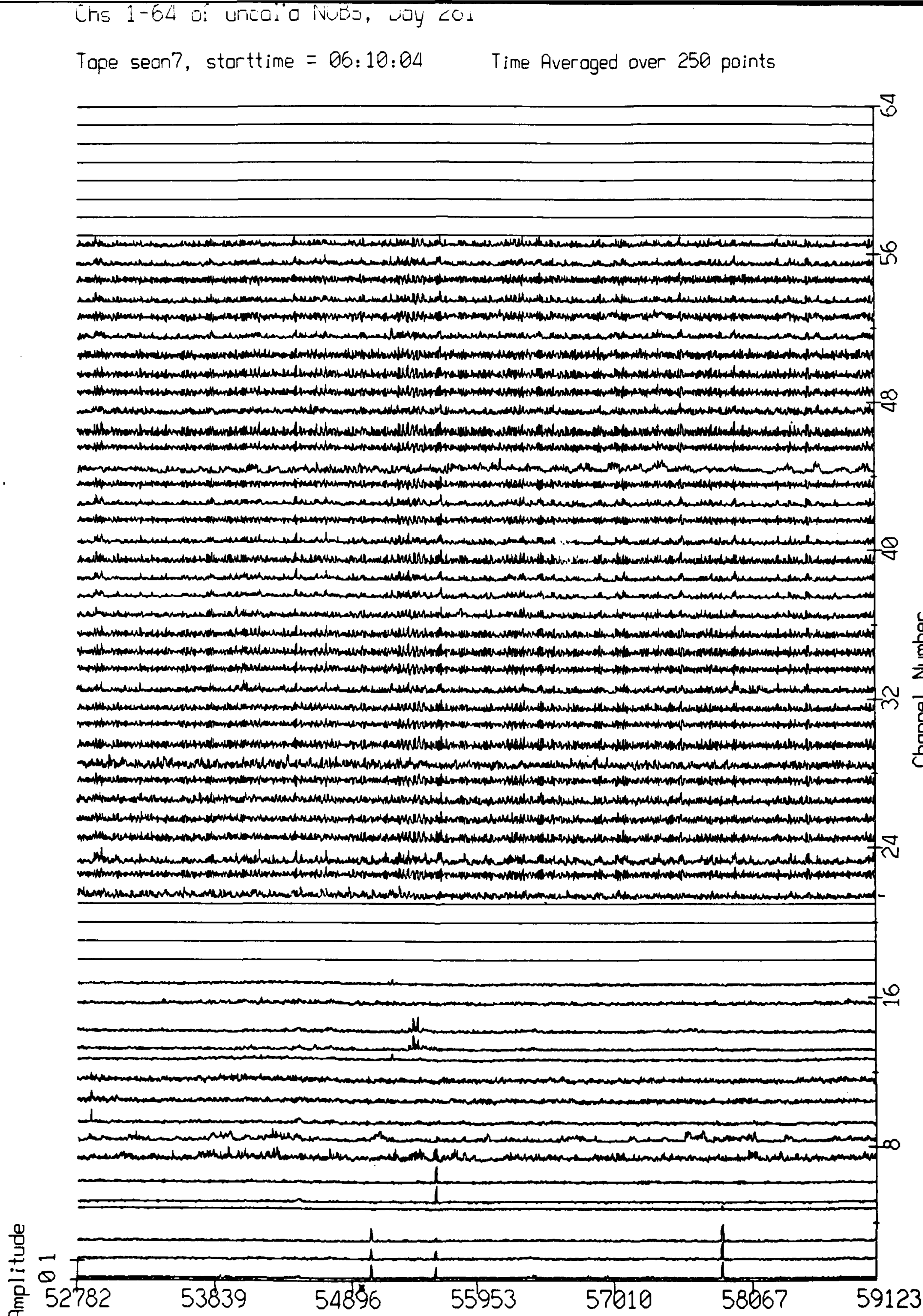


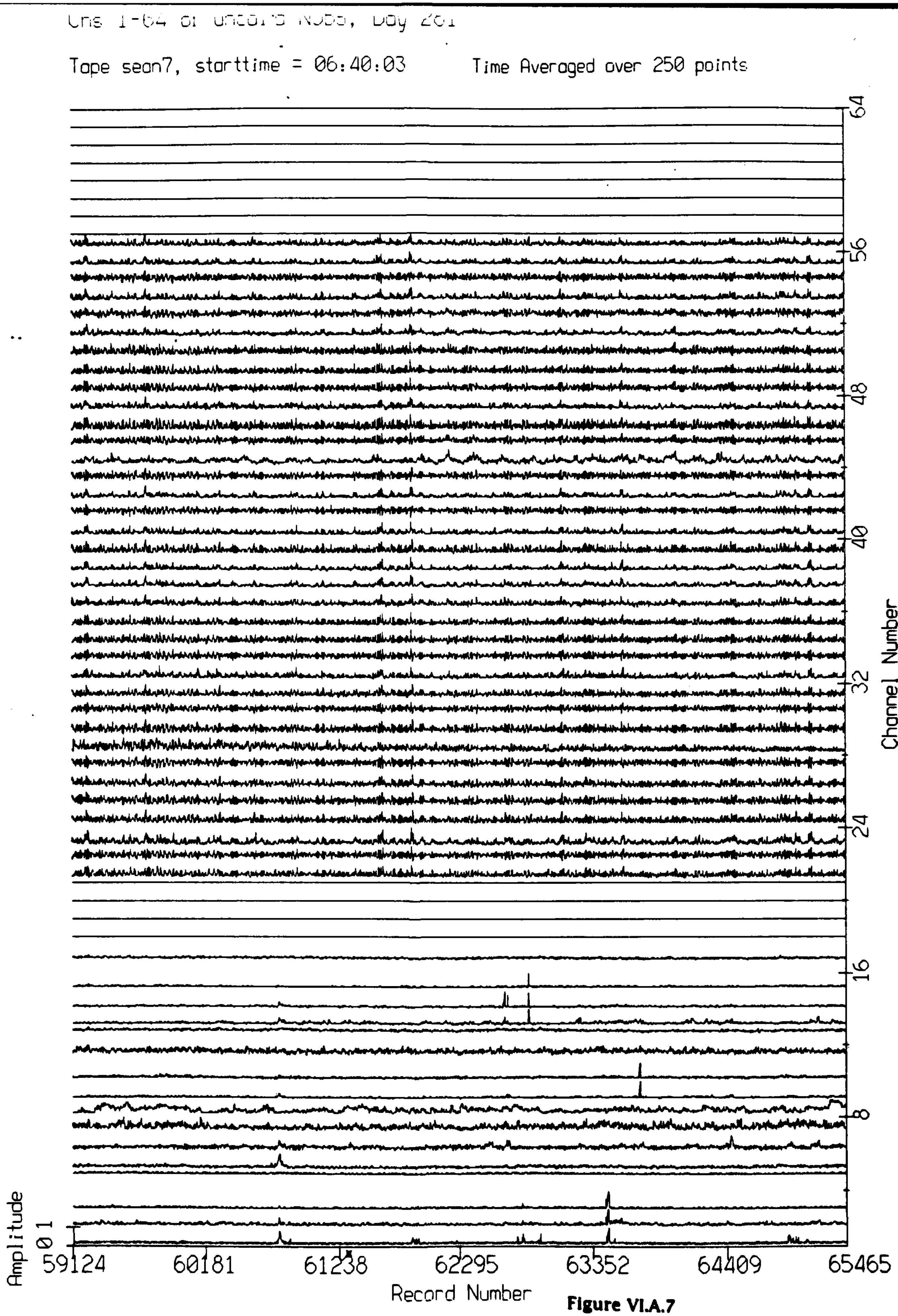
Figure VI.A.4



Chs 1-64 of un-cal'd NUB5, Day 281
Tape sean7, starttime = 05:40:01
Time Averaged over 250 points
64
56
48
40
32
24
16
8
Channel Number
Amplitude
0 1
46440
47497
48554
49611
50668
51725
52781
Record Number

Figure VI.A.5


Chs 1-64 of uncal'd NUBS, Day 201
Tape sean7, starttime = 06:10:04
Time Averaged over 250 points
64
56
48
40
32
24
16
8
Channel Number
Amplitude
0 1
52782
53839
54896
55953
57010
58067
59123
Record Number
Figure VI.A.6



Tape sean7, starttime = 06:40:03
Time Averaged over 250 points
64
56
48
40
32
24
16
8
Channel Number
Amplitude
0 1
59124
60181
61238
62295
63352
64409
65465
Record Number

Figure VI.A.7

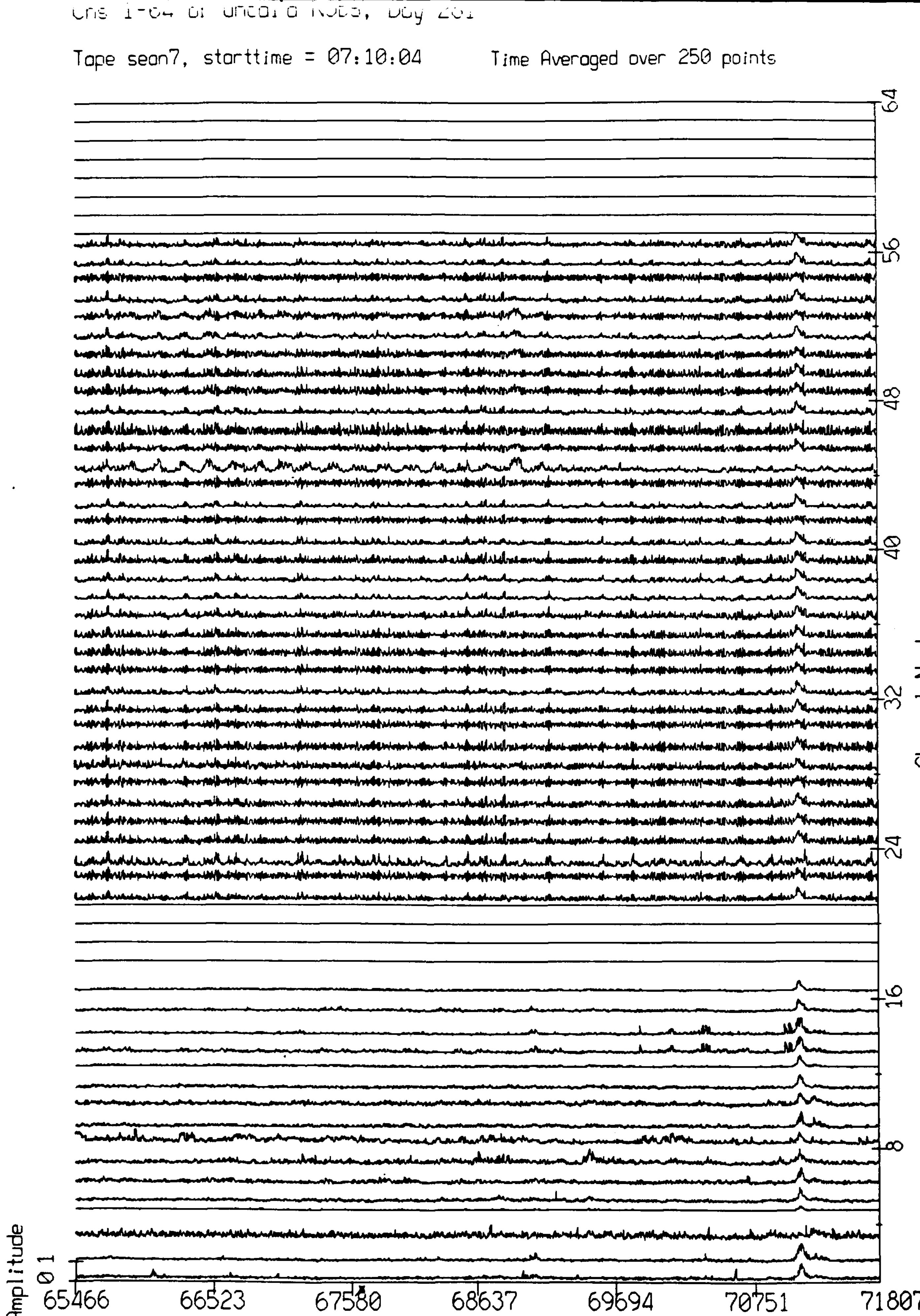

Chs 1-64 of unc01a N0D3, Day 201
Tape sean7, starttime = 07:10:04
Time Averaged over 250 points
64
56
48
40
32
24
16
8
Channel Number
Amplitude
0 1
65466
66523
67580
68637
69694
70751
71807
Record Number

Figure VI.A.8

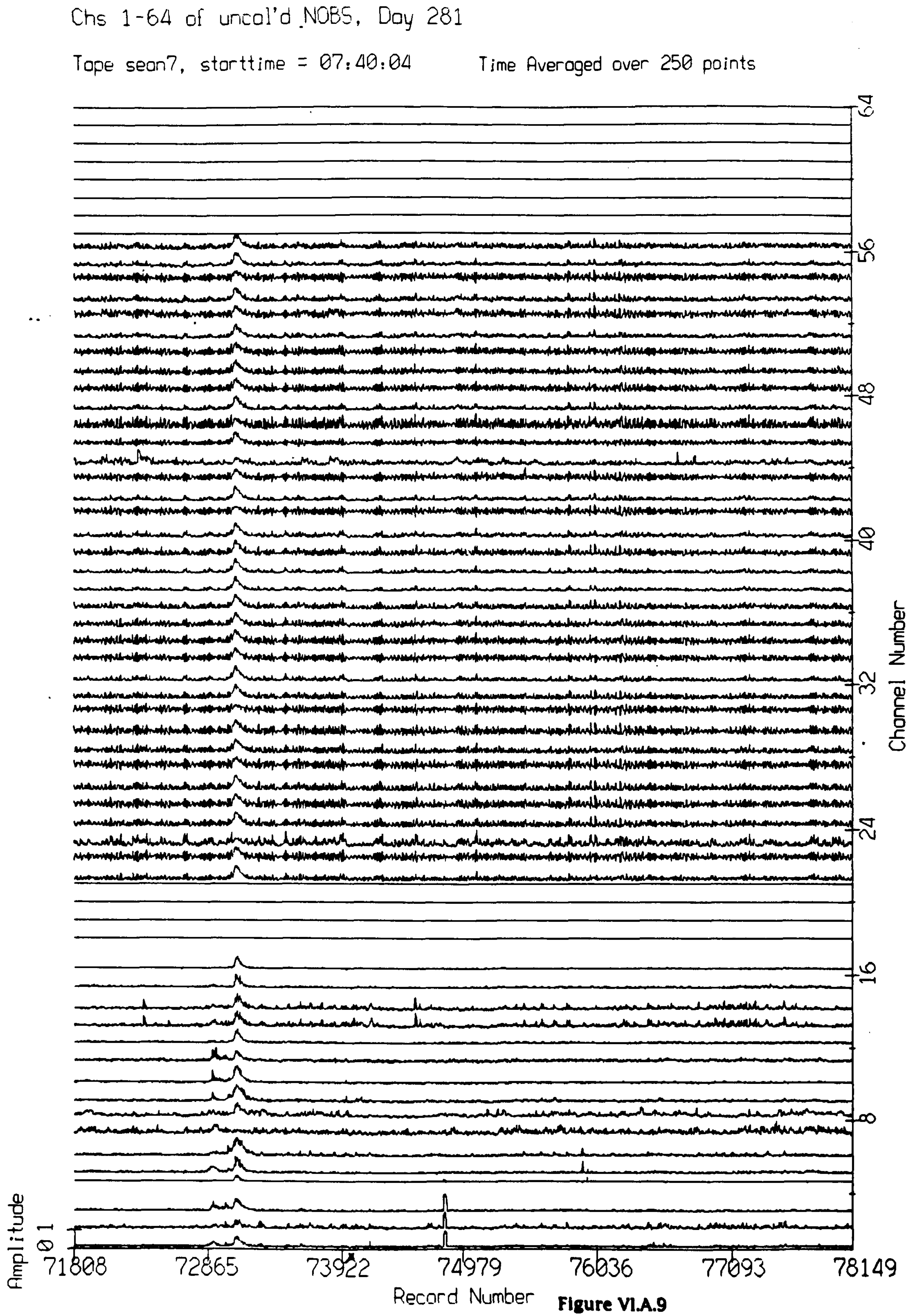

Chs 1-64 of uncal'd NOBS, Day 281
Tape sean7, starttime = 07:40:04
Time Averaged over 250 points
64
56
48
40
32
24
16
8
Channel Number
Amplitude
0 1
71808
72865
73922
74979
76036
77093
78149
Record Number

Figure VI.A.9

Chs 1-64 of uncoil'd NU65, Day 261

Tape sean7, starttime = 08:40:06 Time Averaged over 250 points

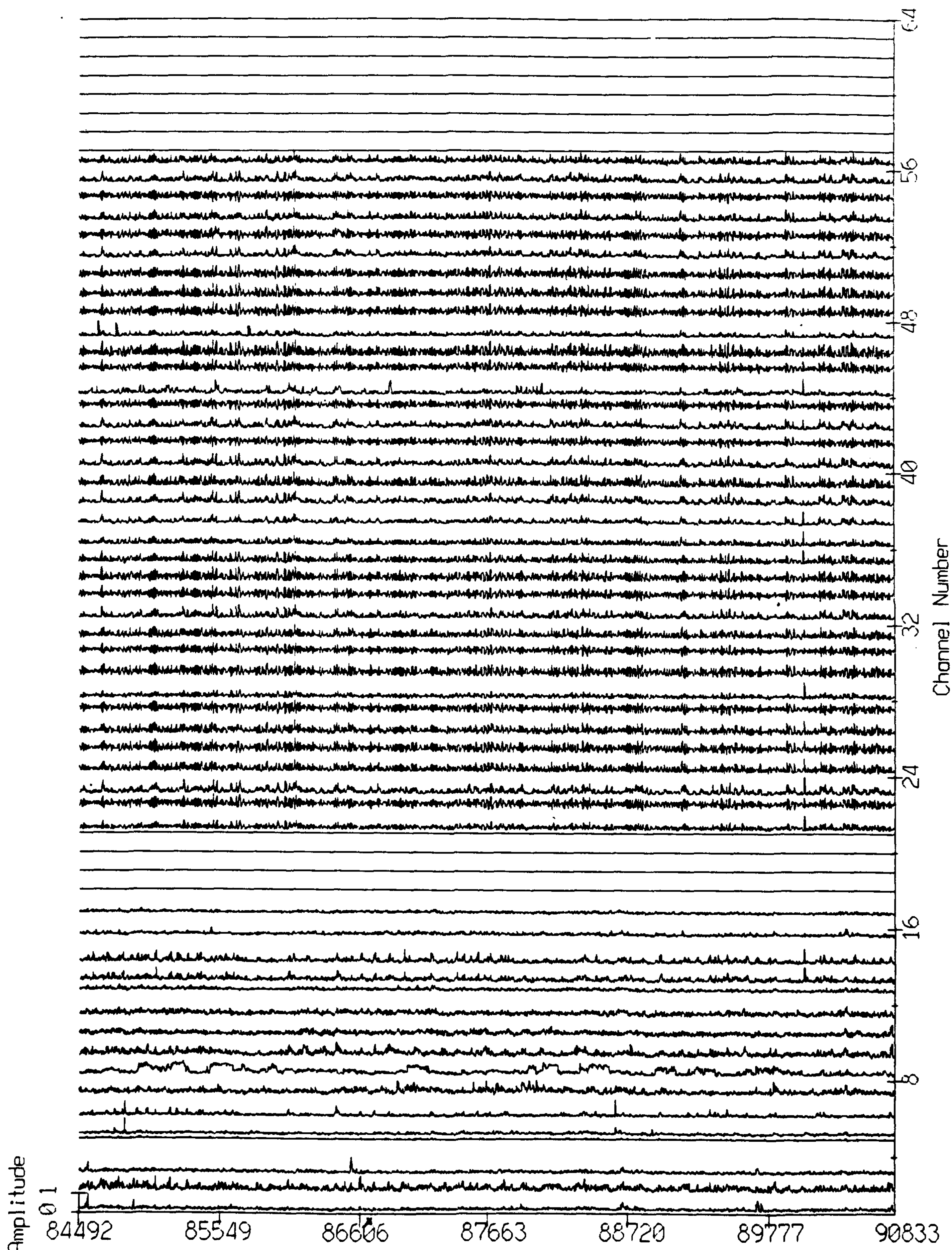


Figure VI.A.10

Chs 1-64 of uncal'd Nods, Day 201

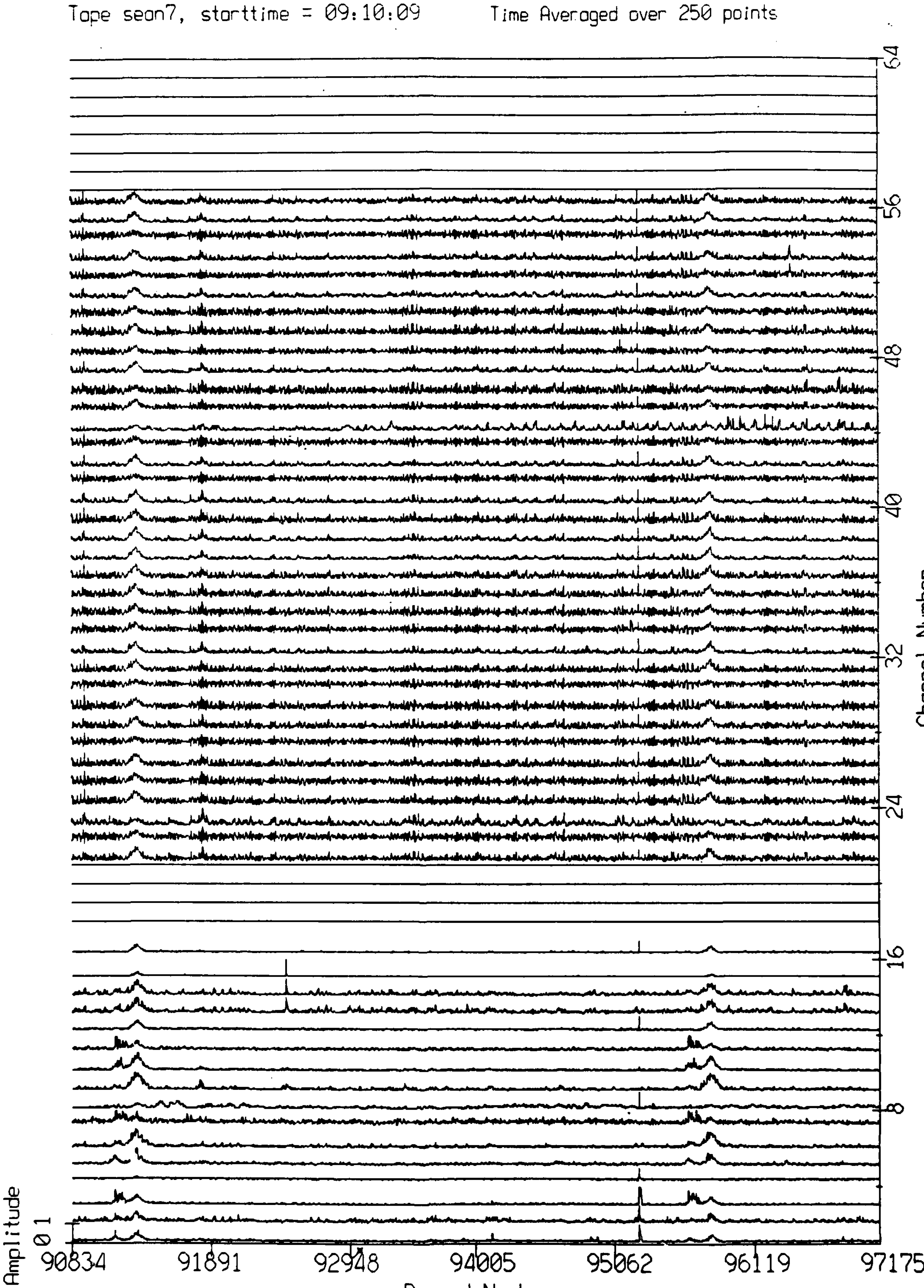


Figure VI.A.11

Chs 1-64 of uncal'd NOBS, Day 281

Tape sean7, starttime = 09:40:11 Time Averaged over 250 points

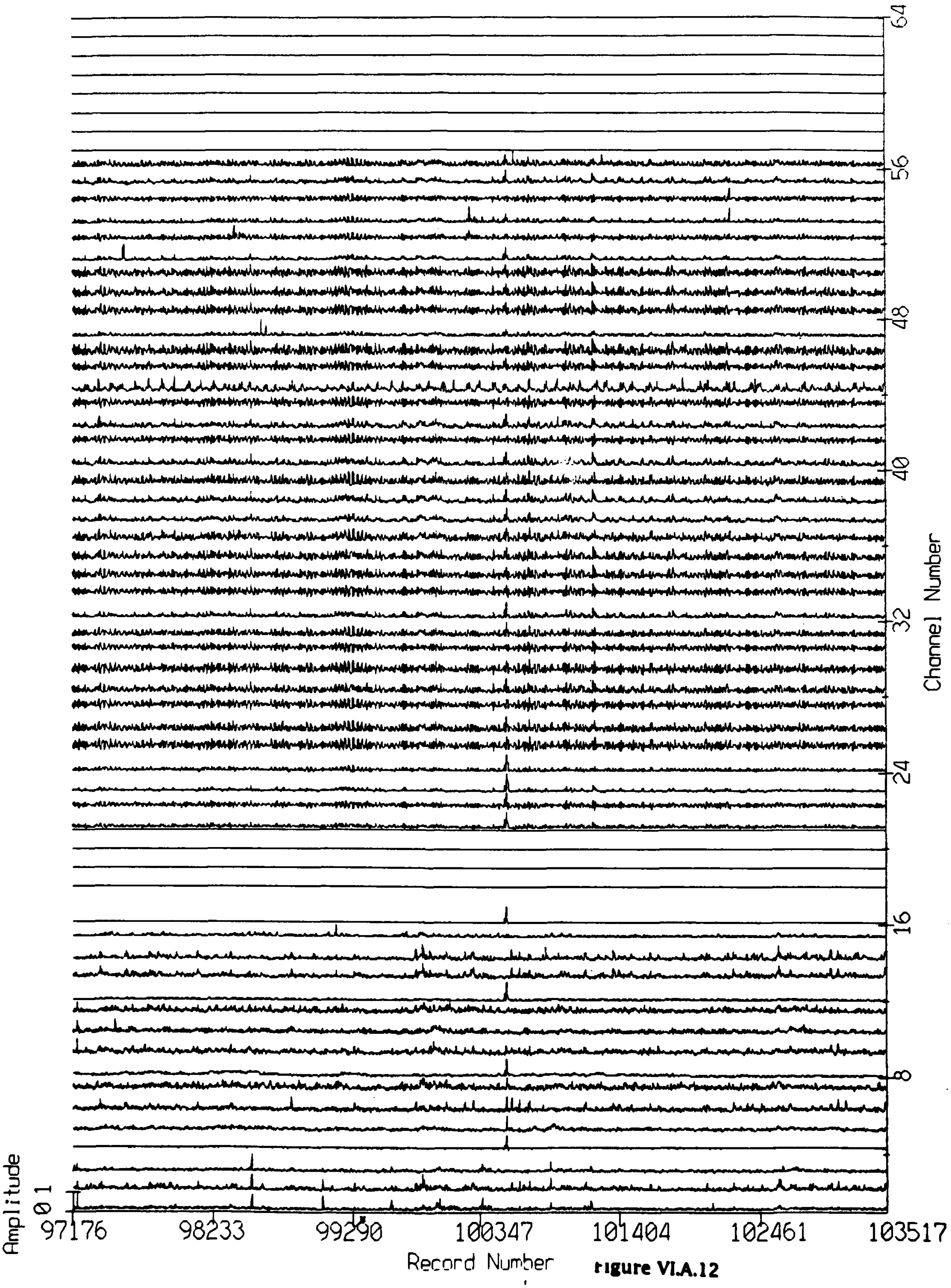


Figure VI.A.12

Chs 1-64 at Unocal Node, Day 201

Tape sean7, starttime = 10:10:14 Time Averaged over 250 points

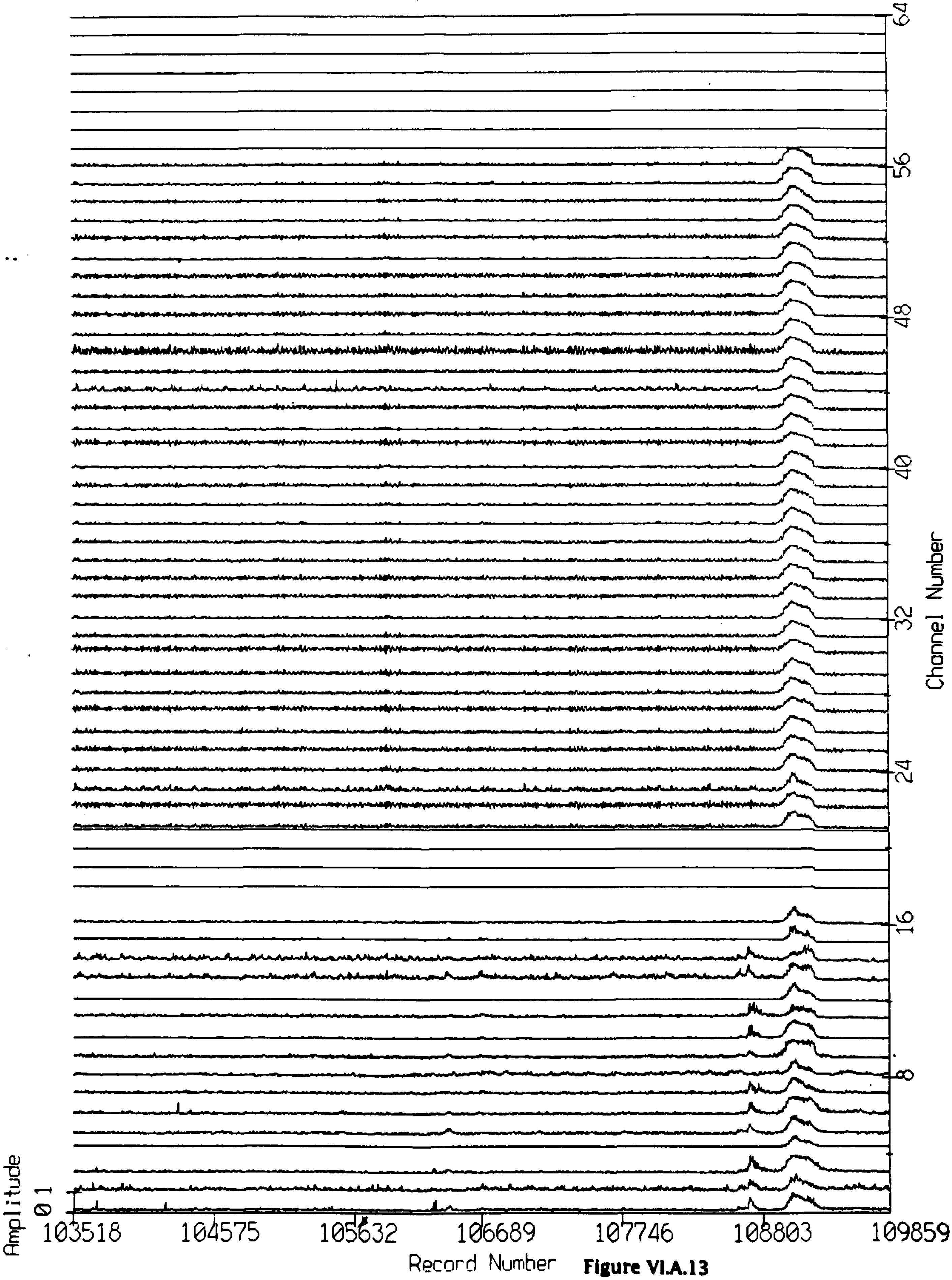


Figure VI.A.13

Tape sean7, starttime = 10:40:17 Time Averaged over 250 points

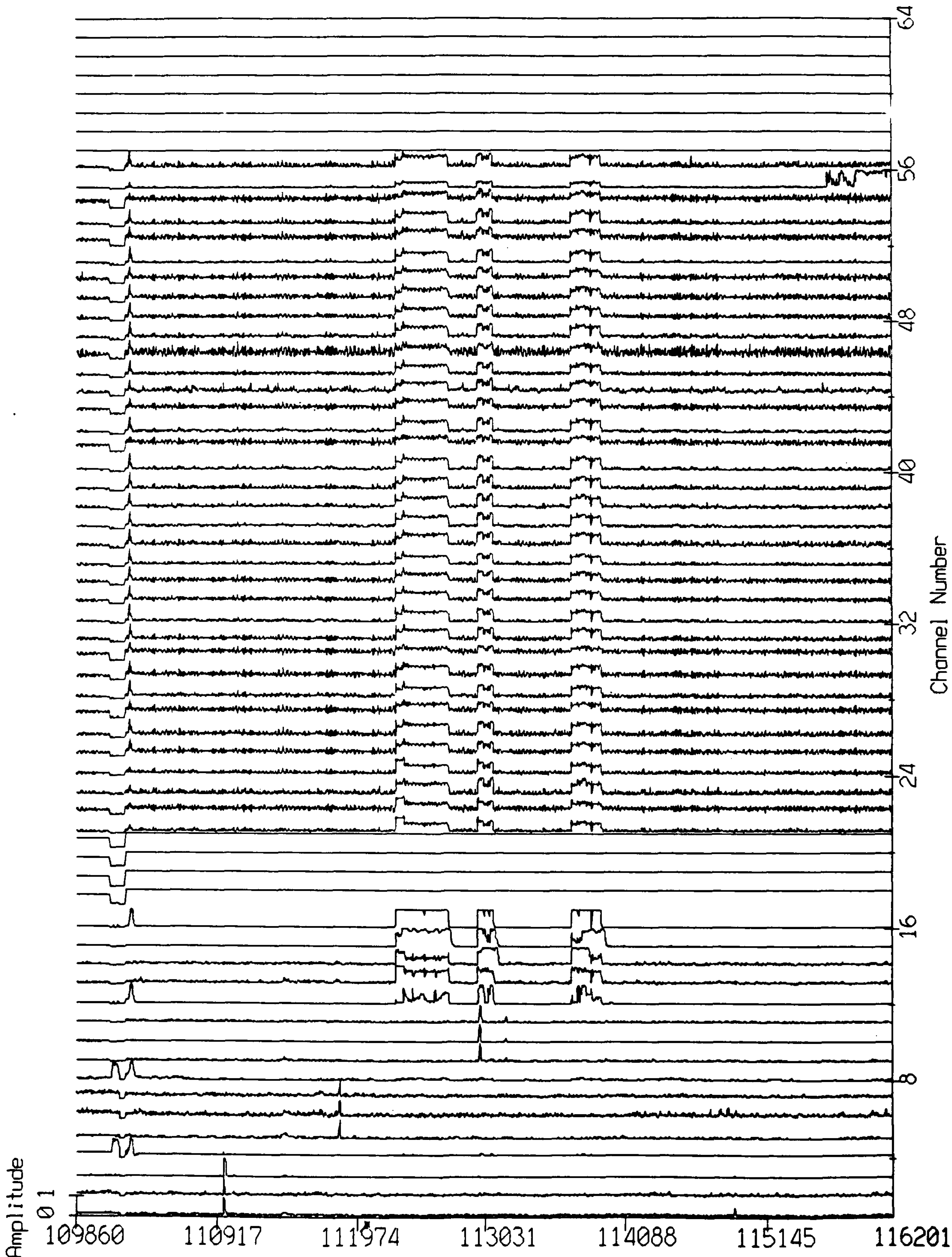


Figure VI.A.14

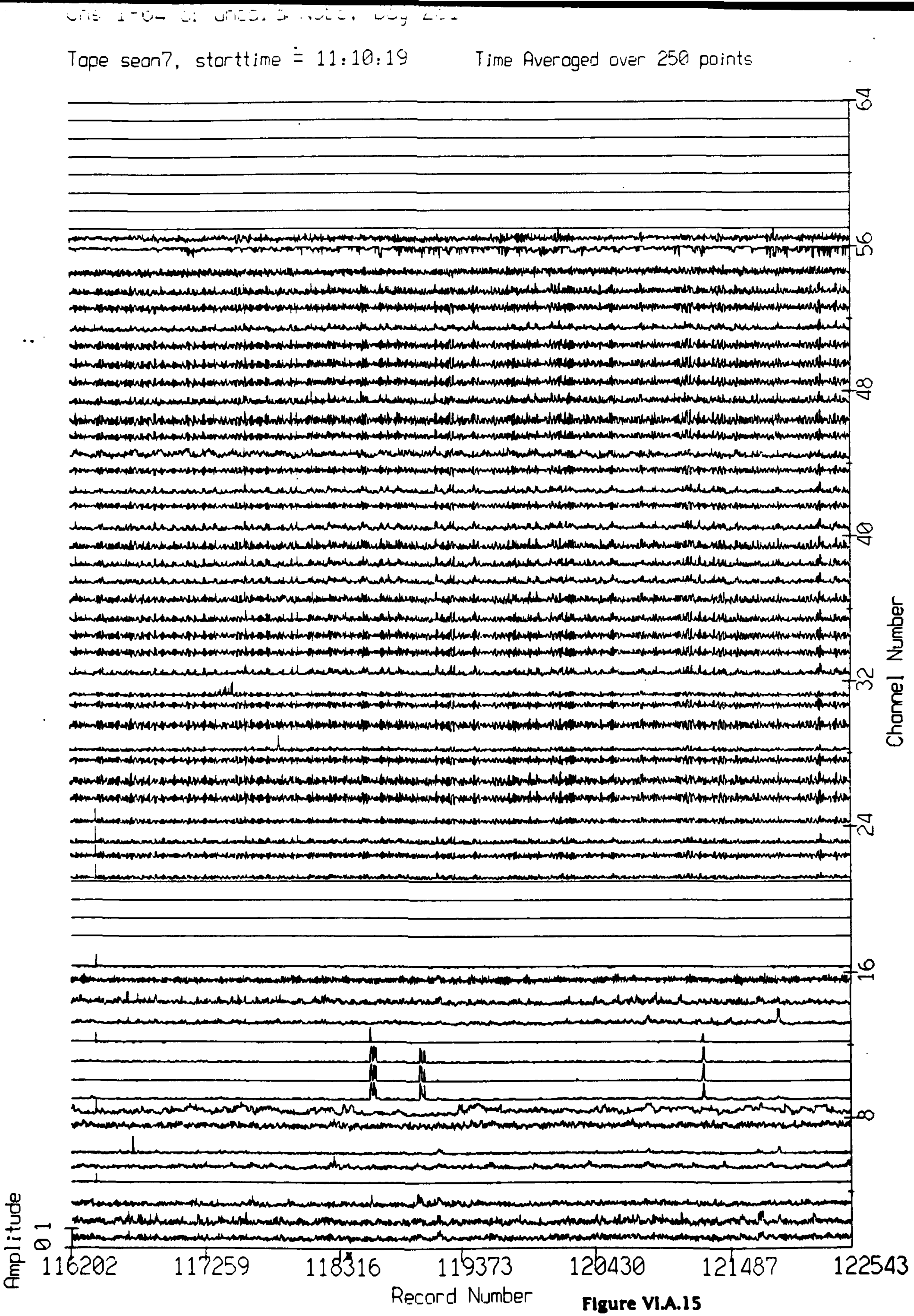


Figure VI.A.15

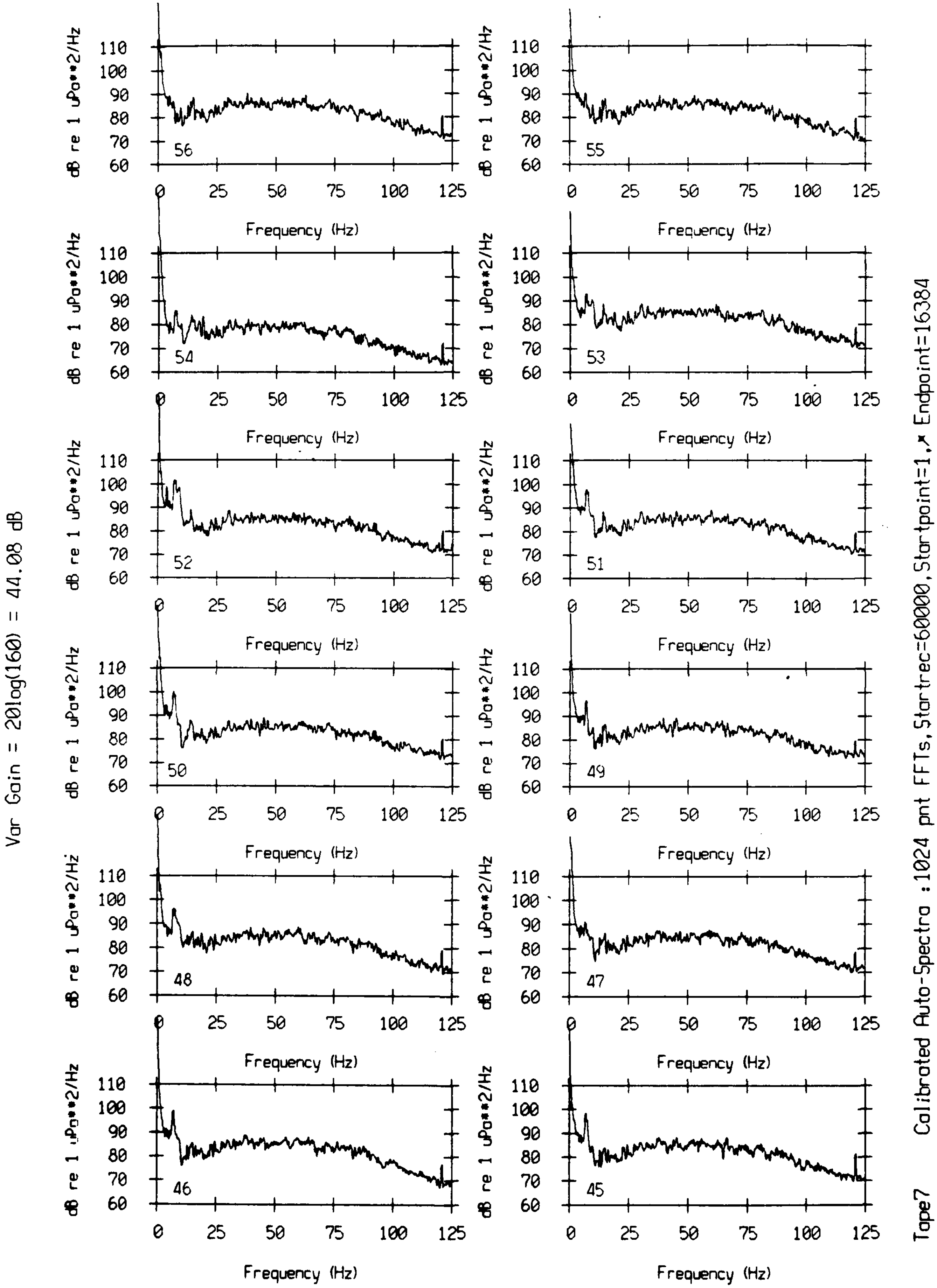

Var Gain = 20log(160) = 44.08 dB
Tape7 Calibrated Auto-Spectra :1024 pnt FFTs,Startrec=60000,Startpoint=1,* Endpoint=16384
dB re 1 uPa**2/Hz
Frequency (Hz)
56
55
54
53
52
51
50
49
48
47
46
45

Figure VI.B.1

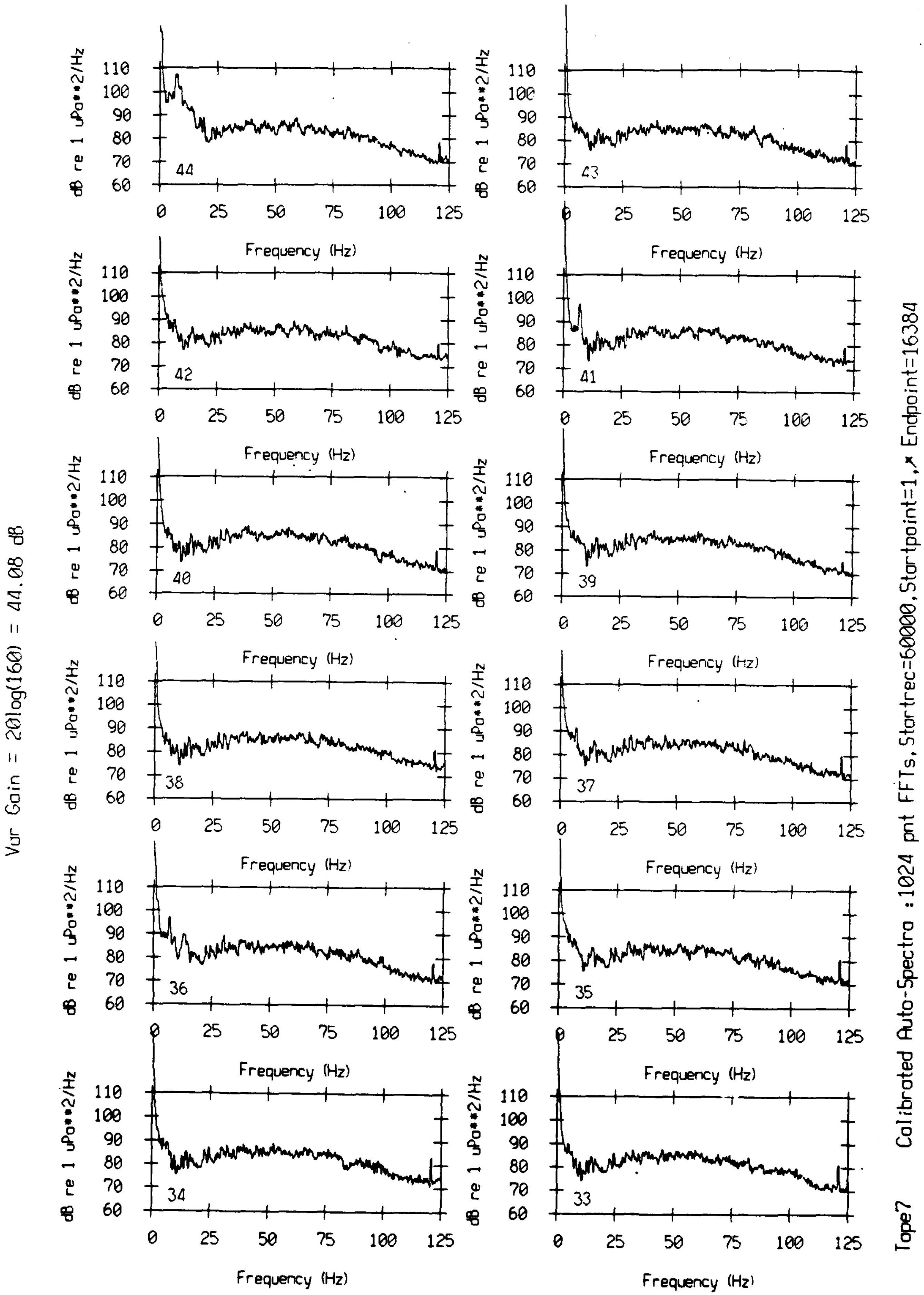

Var Gain = 20log(160) = 44.08 dB
Tape7 Calibrated Auto-Spectra :1024 pnt FFTs, Startrec=60000, Startpoint=1, Endpoint=16384
dB re 1 uPa**2/Hz
Frequency (Hz)
44
43
42
41
40
39
38
37
36
35
34
33

Figure V 1.B.2

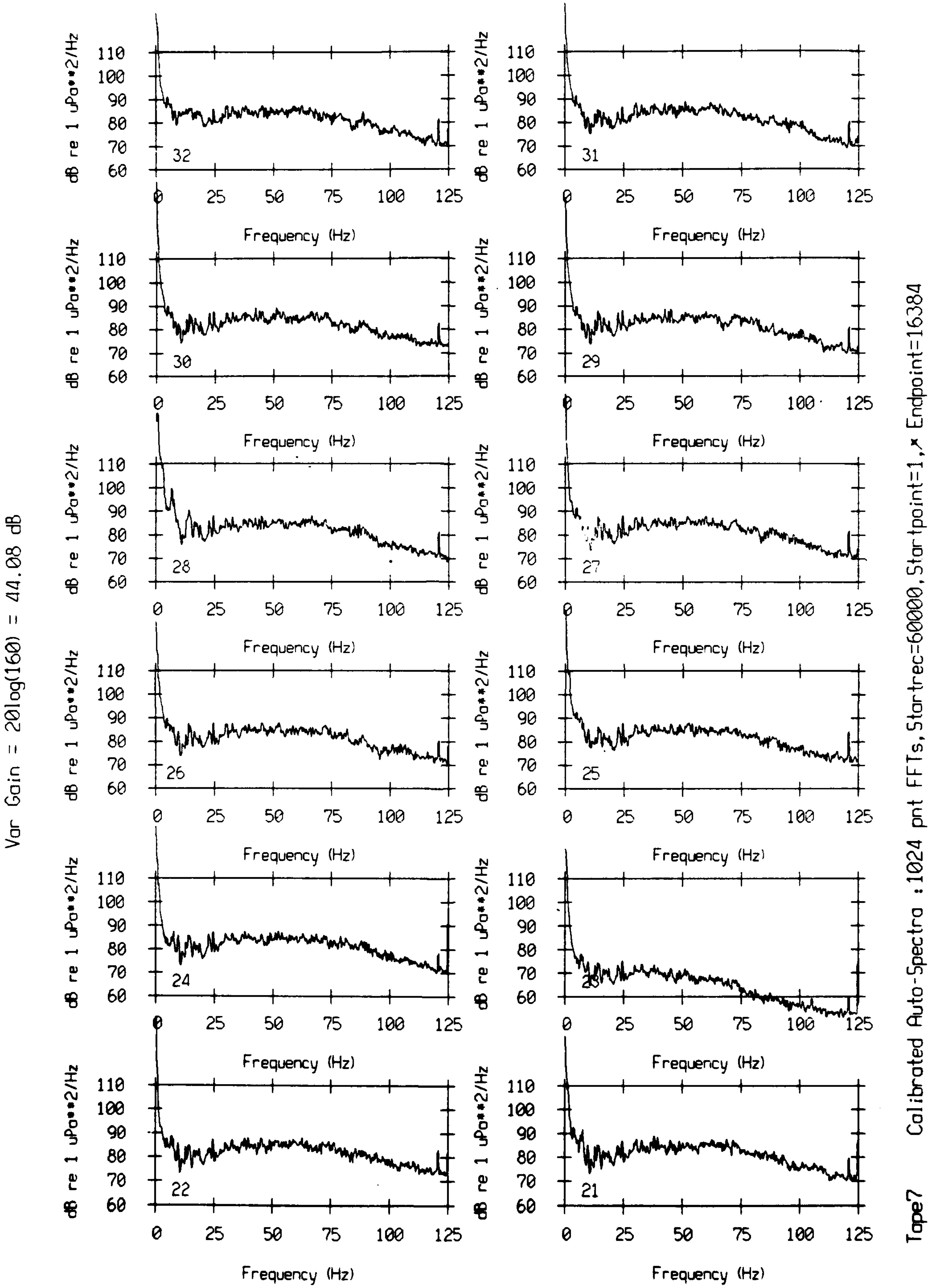
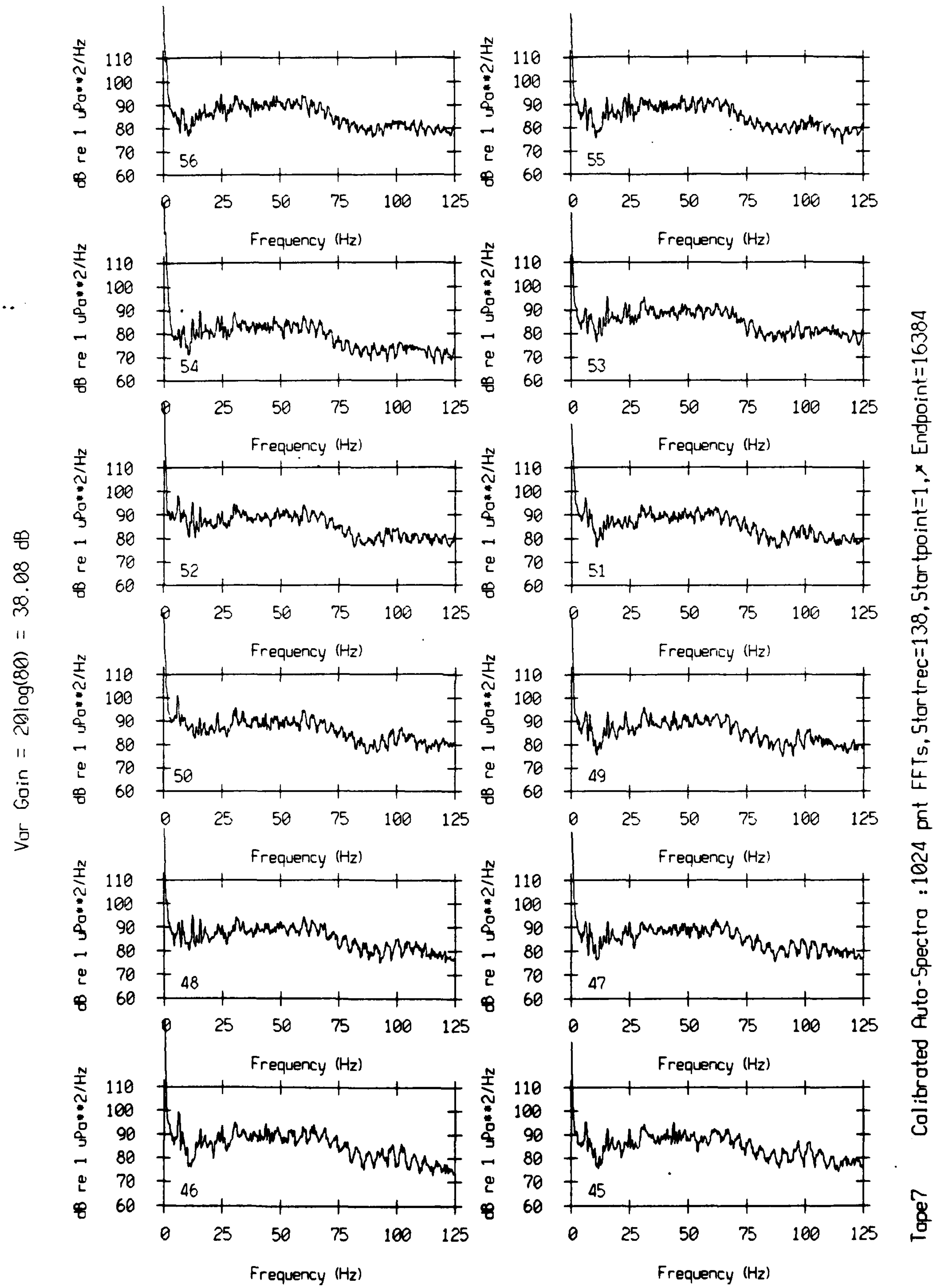

Var Gain = 20log(160) = 44.08 dB
Calibrated Auto-Spectra :1024 pnt FFTs, Startrec=60000, Startpoint=1, Endpoint=16384
Tape7
dB re 1 uPa**2/Hz
Frequency (Hz)
32
31
30
29
28
27
26
25
24
23
22
21

Figure VI.B.3



Var Gain = 20log(80) = 38.08 dB
Tape7 Calibrated Auto-Spectra :1024 pnt FFTs, Startrec=138, Startpoint=1, Endpoint=16384
dB re 1 uPa**2/Hz
Frequency (Hz)
56
55
54
53
52
51
50
49
48
47
46
45

Figure VI.B.4

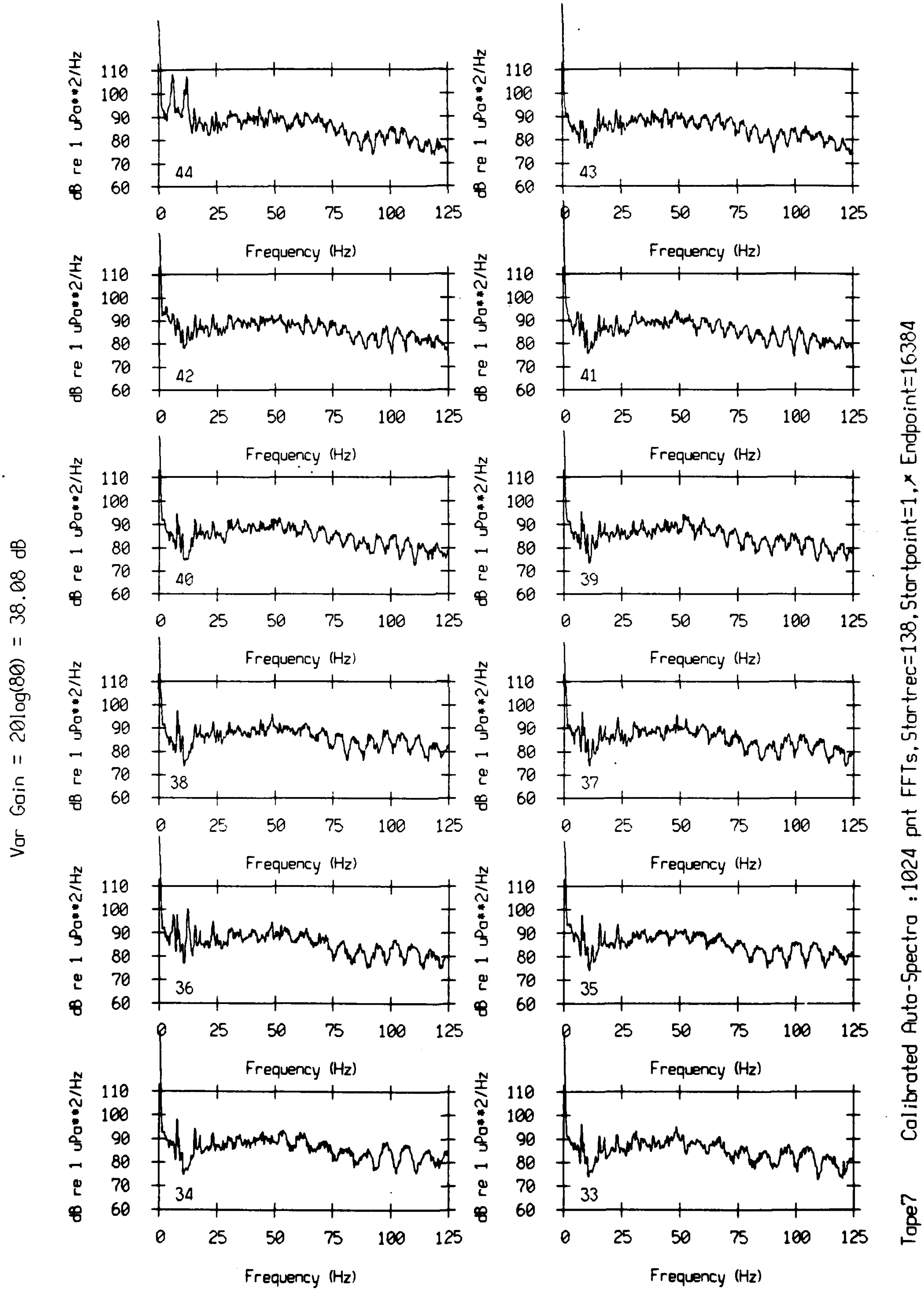
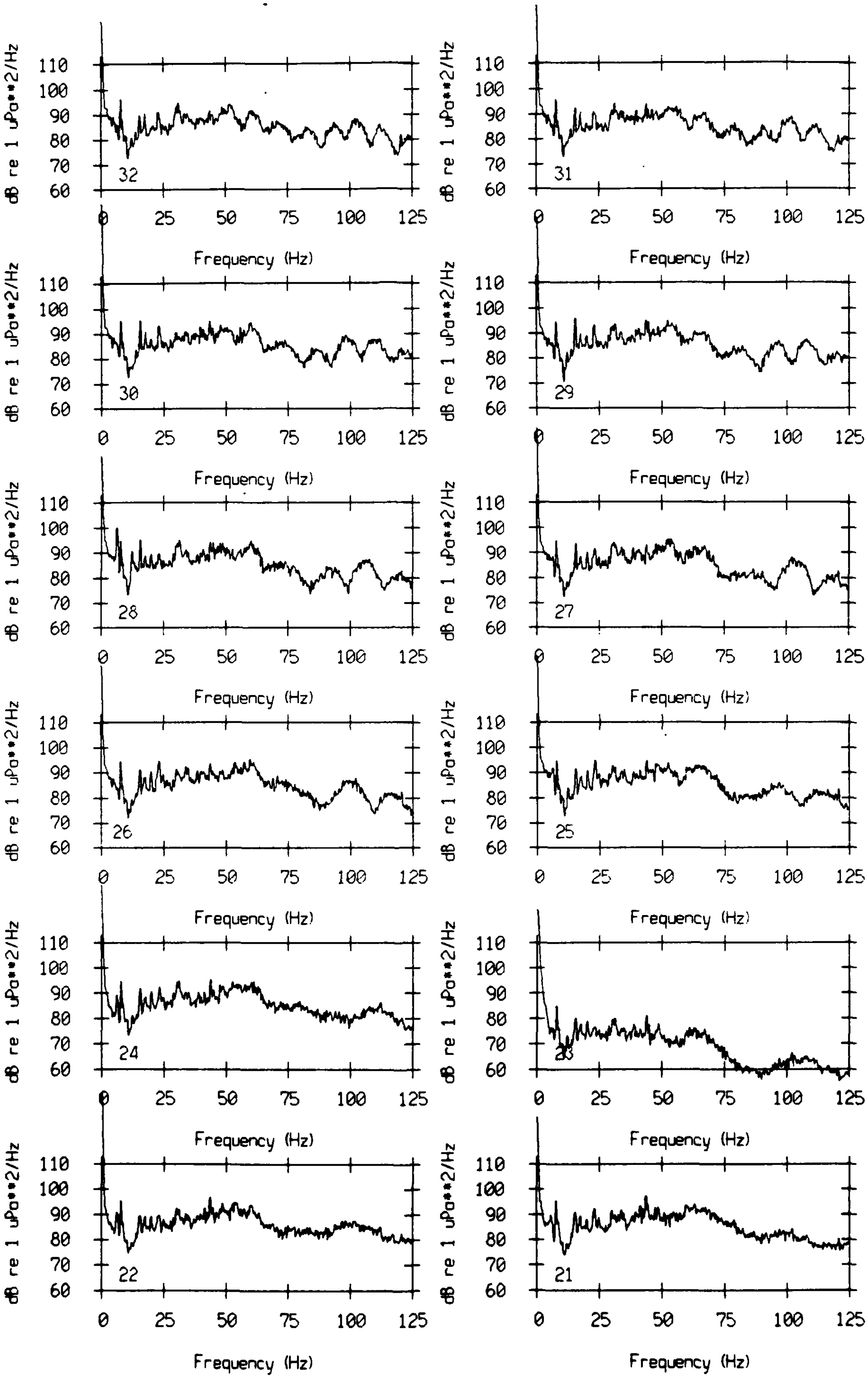

Var Gain = 20log(80) = 38.08 dB
Tape7   Calibrated Auto-Spectra :1024 pnt FFTs, Startrec=138, Startpoint=1, Endpoint=16384
dB re 1 uPa**2/Hz
Frequency (Hz)
44
43
42
41
40
39
38
37
36
35
34
33

Figure VI.B.5

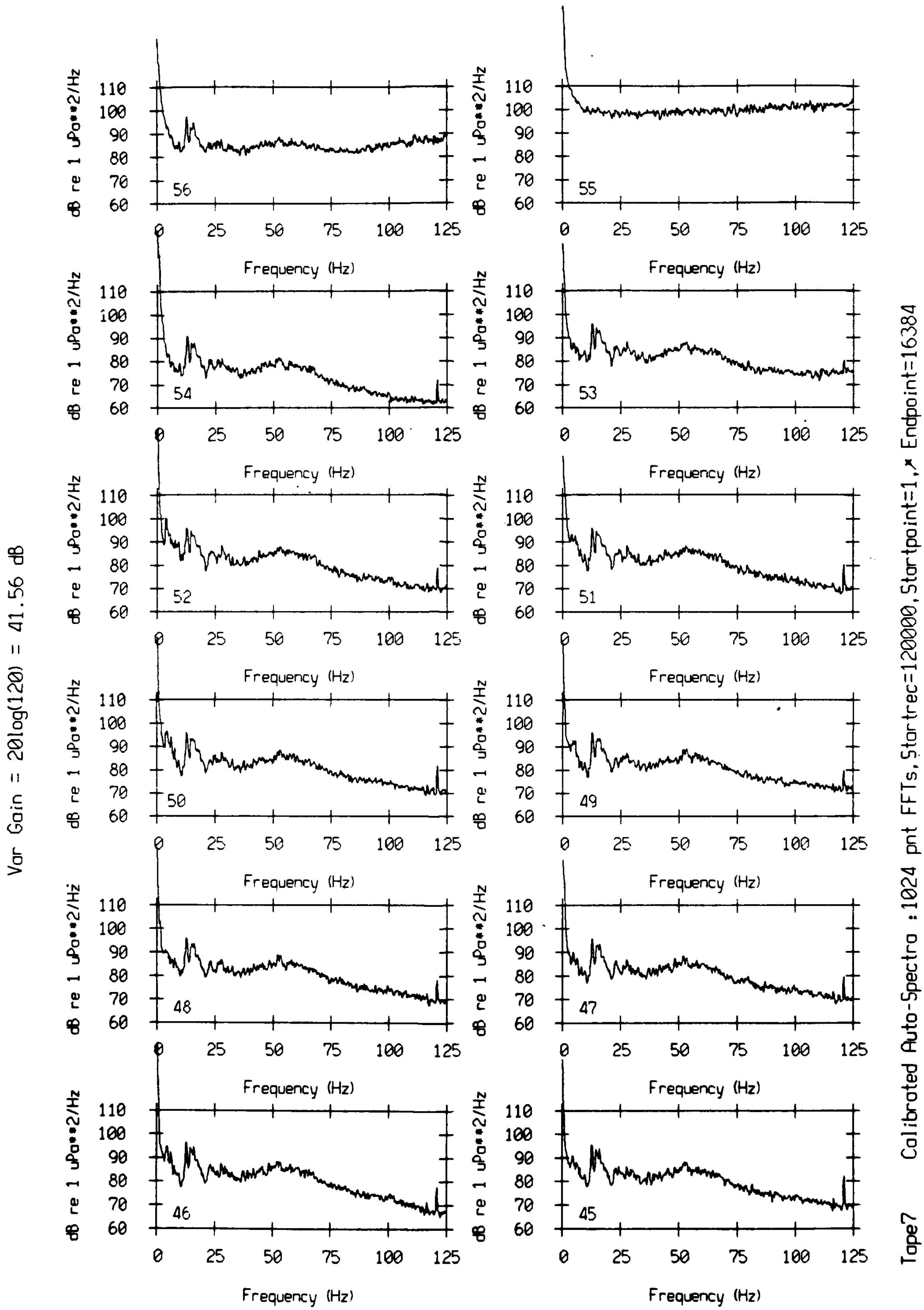
Var Gain = 20log(80) = 38.08 dB



Calibrated Auto-Spectra :1024 pnt FFTs, Startrec=138, Startpoint=1,x Endpoint=16384

Tape7

Figure VI.B.6



Var Gain = 20log(120) = 41.56 dB
Tape7 Calibrated Auto-Spectra :1024 pnt FFTs, Startrec=120000, Startpoint=1, Endpoint=16384
dB re 1 uPa**2/Hz
Frequency (Hz)
56
55
54
53
52
51
50
49
48
47
46
45

Figure VI.B.7

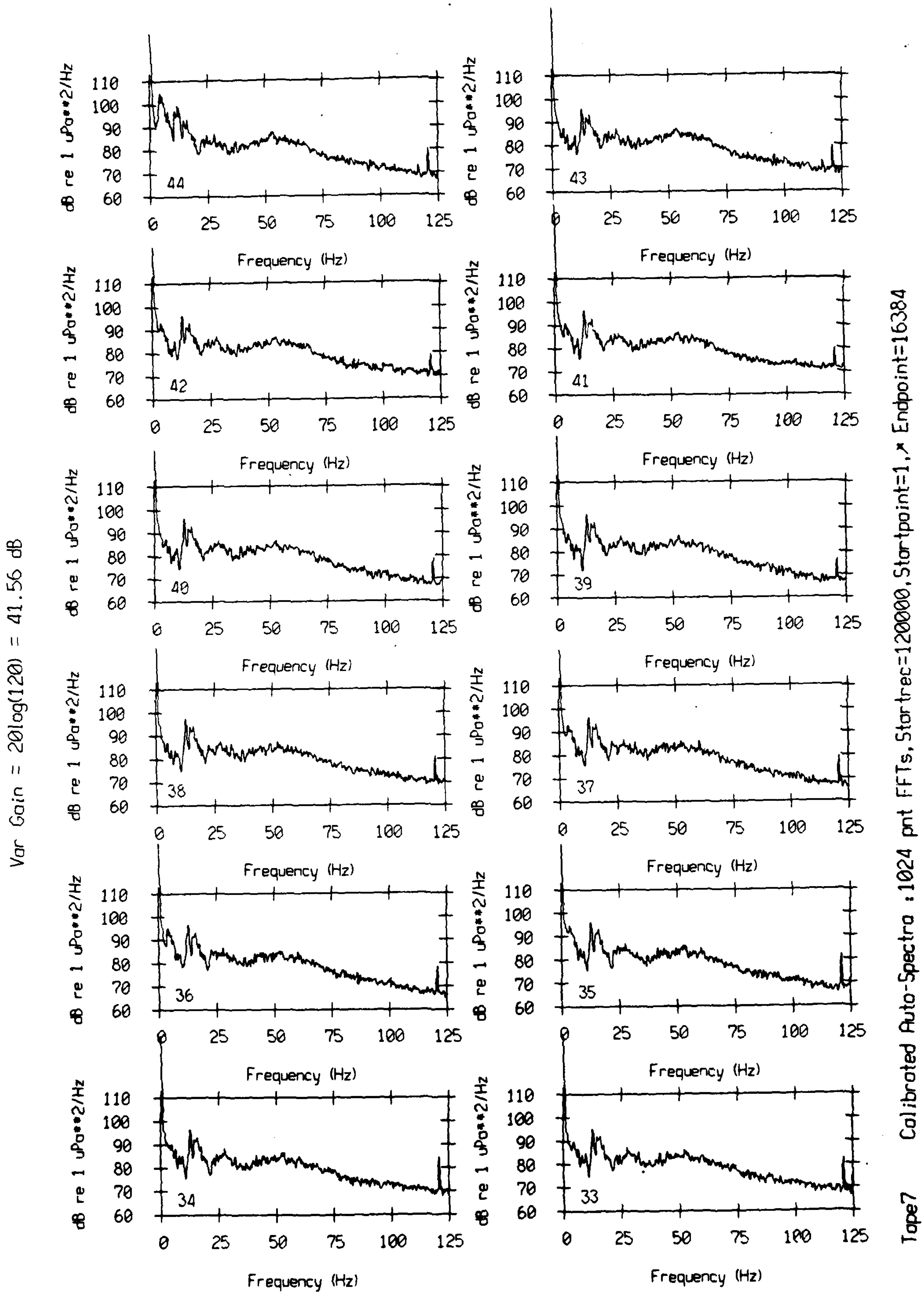

Var Gain = 20log(120) = 41.56 dB
Calibrated Auto-Spectra :1024 pnt FFTs, Startrec=120000, Startpoint=1,* Endpoint=16384
Tape7
dB re 1 uPa**2/Hz
Frequency (Hz)
44
43
42
41
40
39
38
37
36
35
34
33

Figure VI.B.8

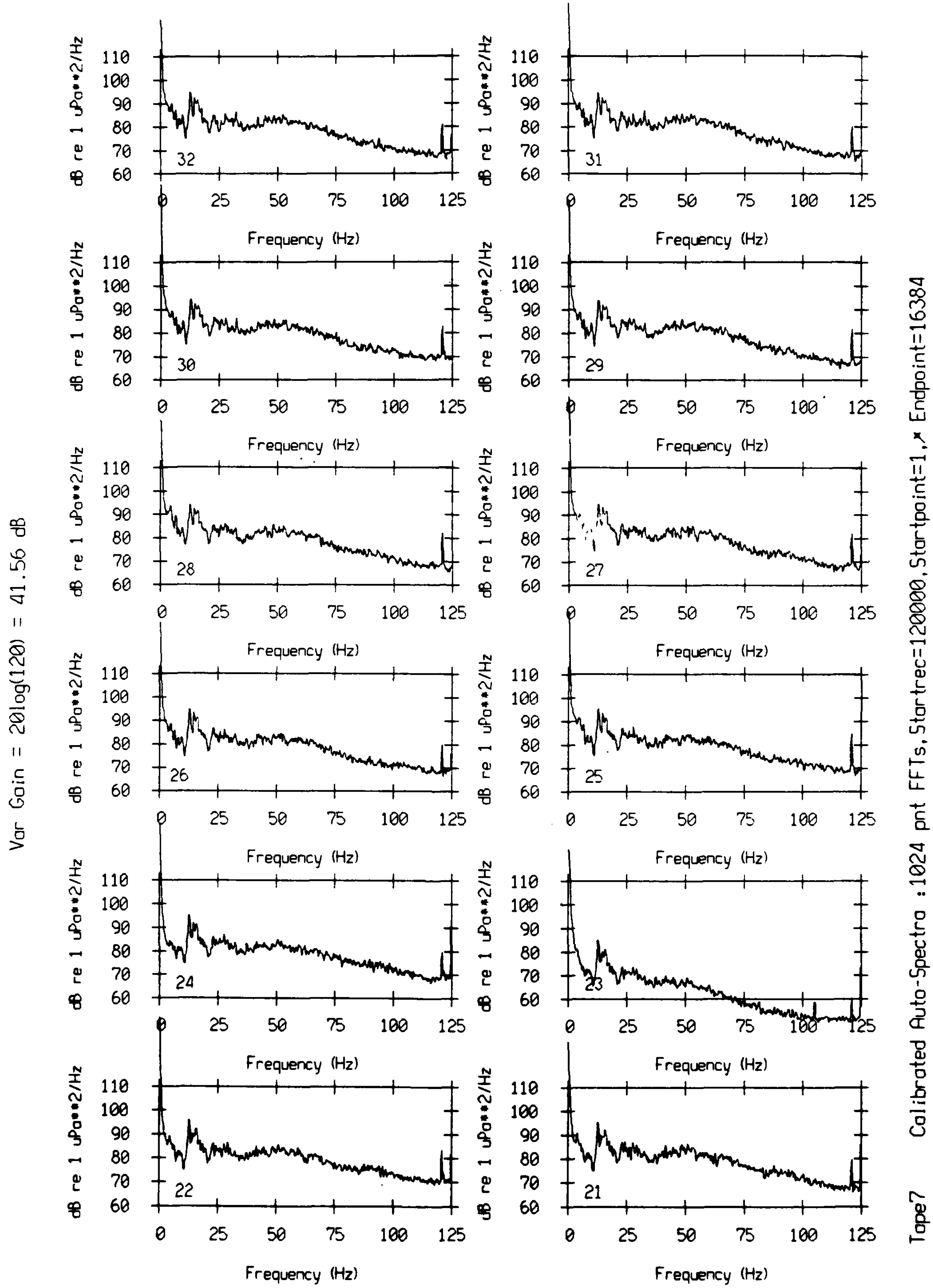

Var Gain = 20log(120) = 41.56 dB
Calibrated Auto-Spectra :1024 pnt FFTs, Startrec=120000, Startpoint=1, Endpoint=16384
Tape7
dB re 1 uPa**2/Hz
Frequency (Hz)
32
31
30
29
28
27
26
25
24
23
22
21

Figure VI.B.9

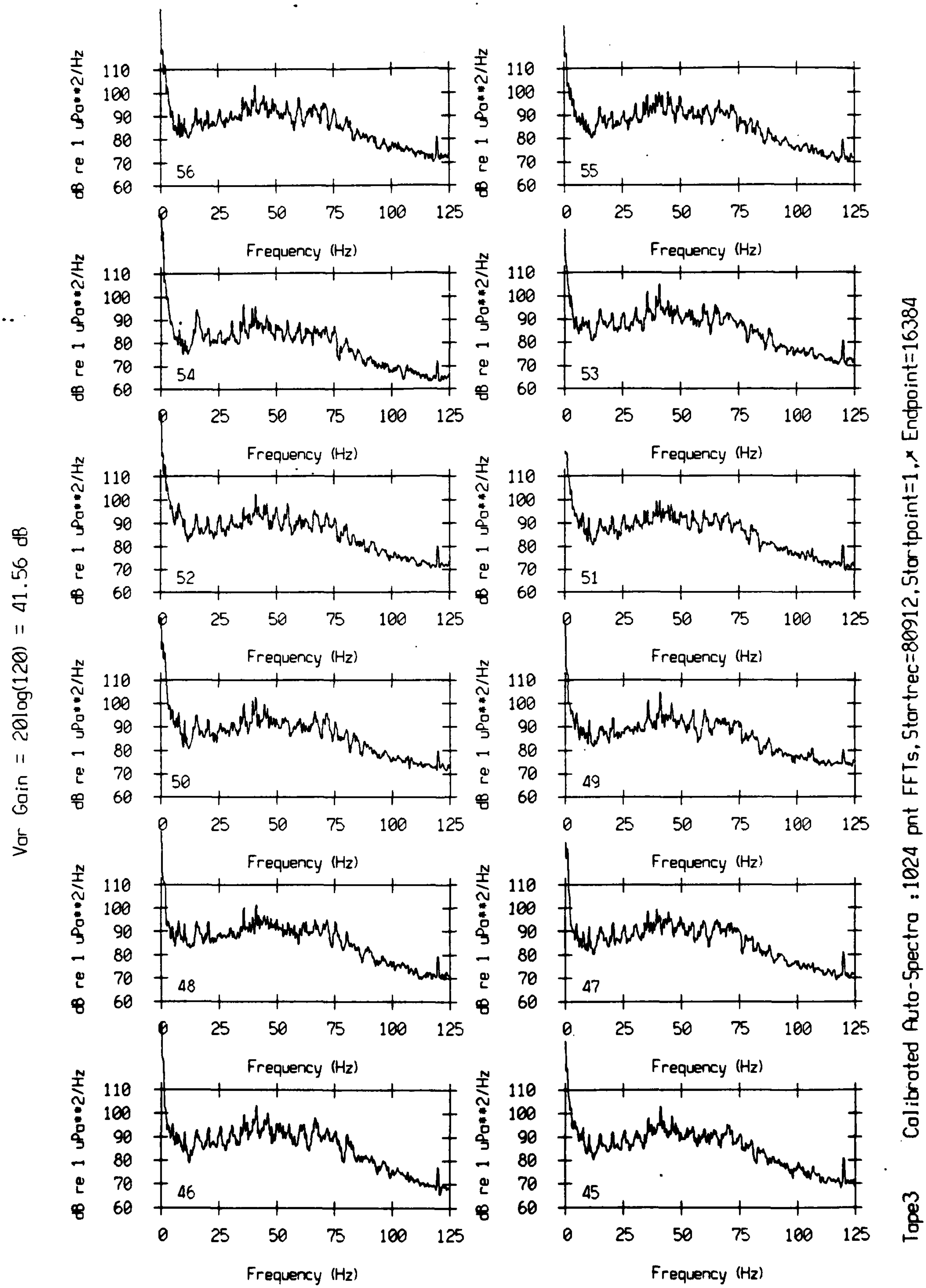


Figure VI.B.10

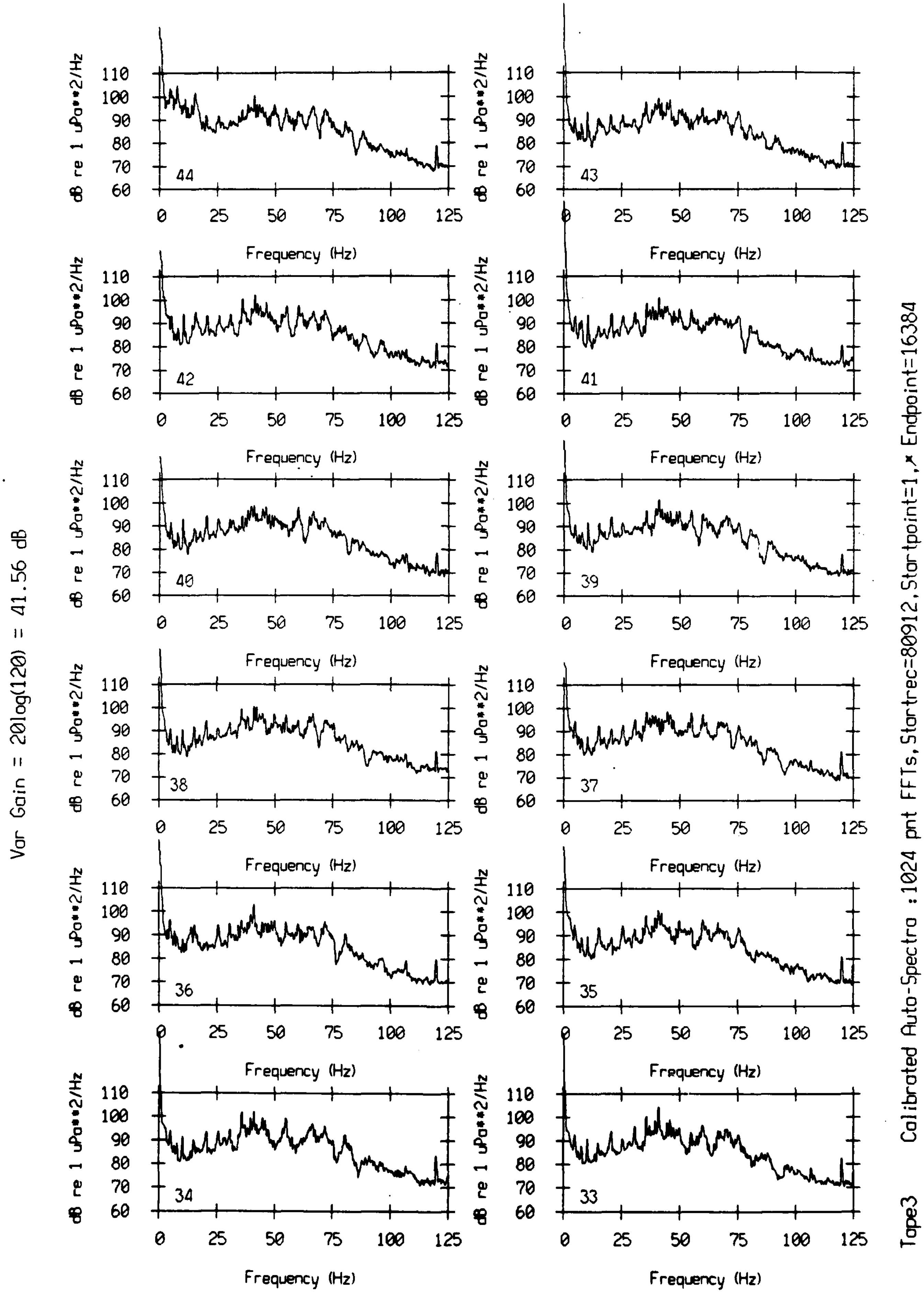


Figure VI.B.11

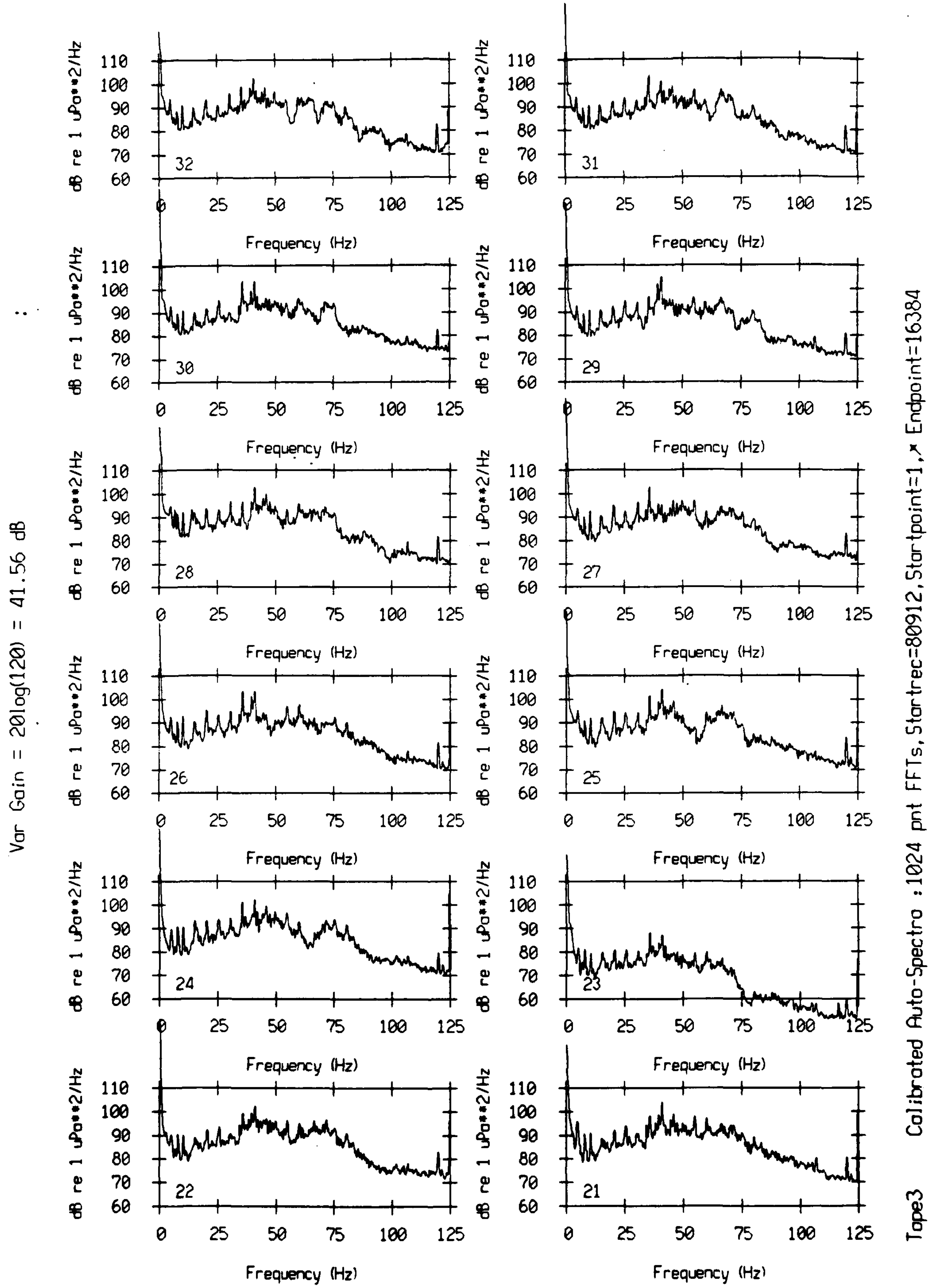


Figure VI.B.12

TAPE: sean7, Normalized time-series

bot16OBS

Desampled every 5 points

Recs 70900 - 71400

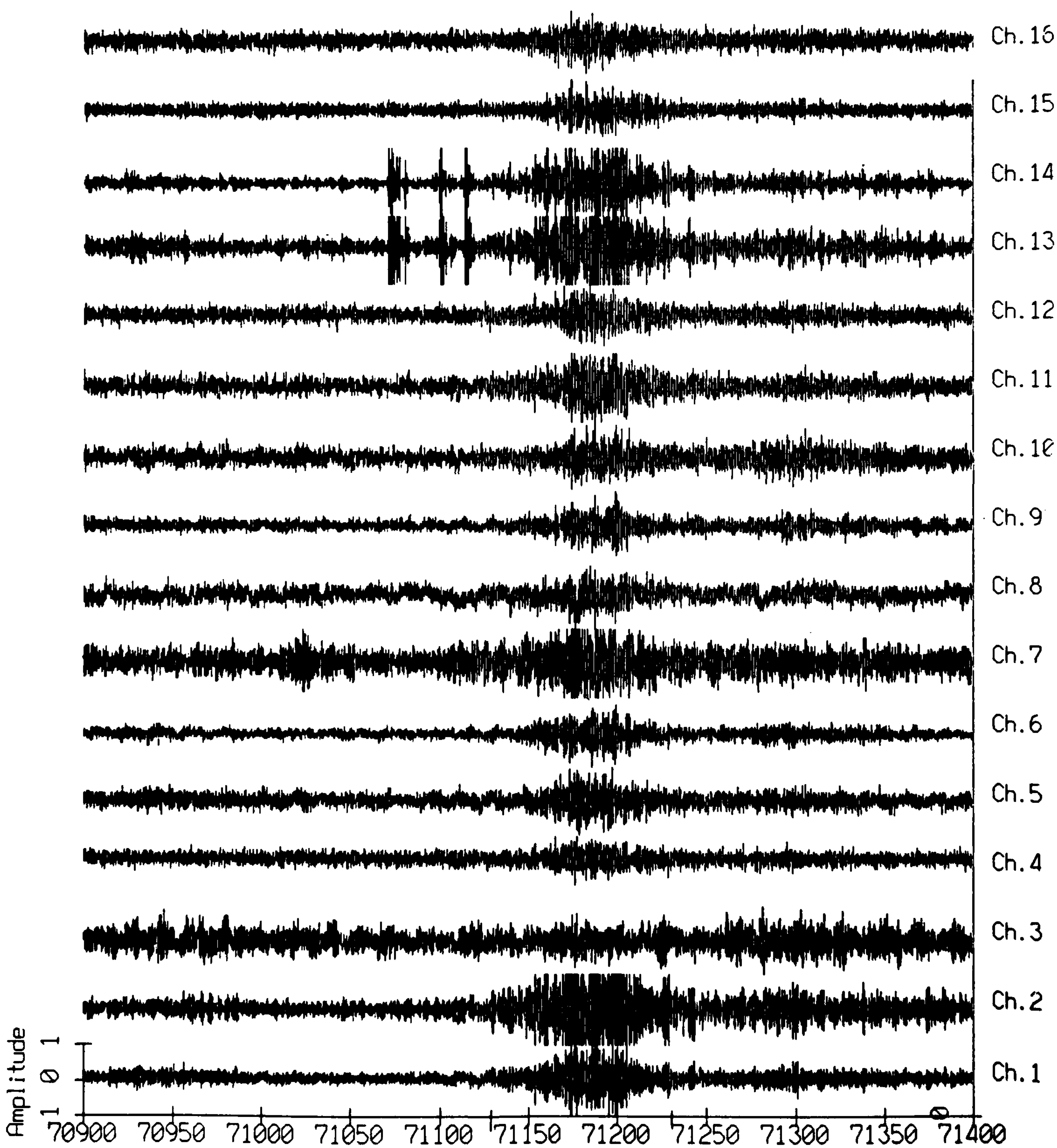


Figure VI.C.1

TAPE: seon7, Normolized time-series

Desompled every 5 points

bot16VAST

Recs 70900 - 71400

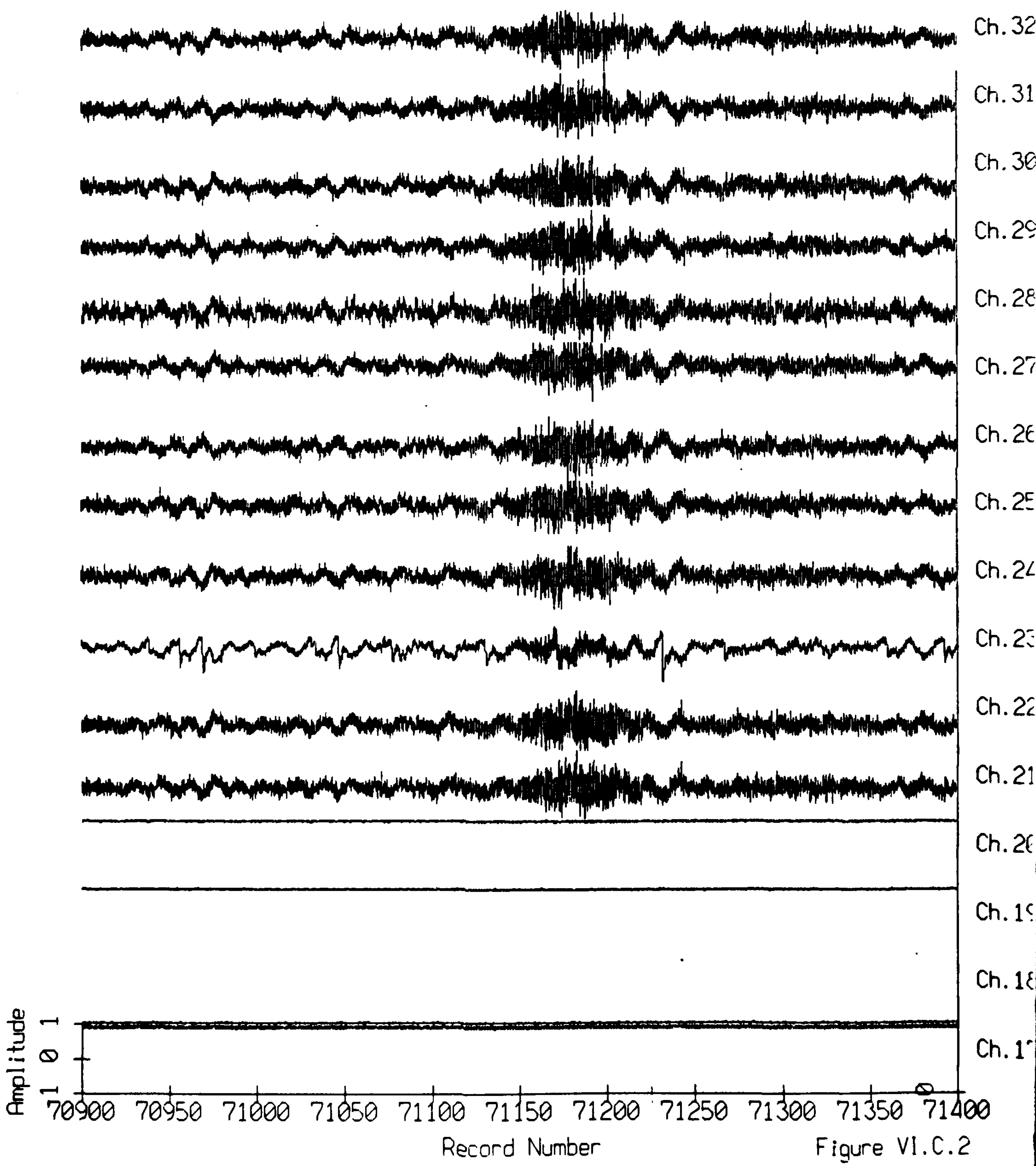


Figure VI.C.2

TAPE: seon7, Normalized time-series

mid16VAST

Desampled every 5 points

Recs 70900 - 71400

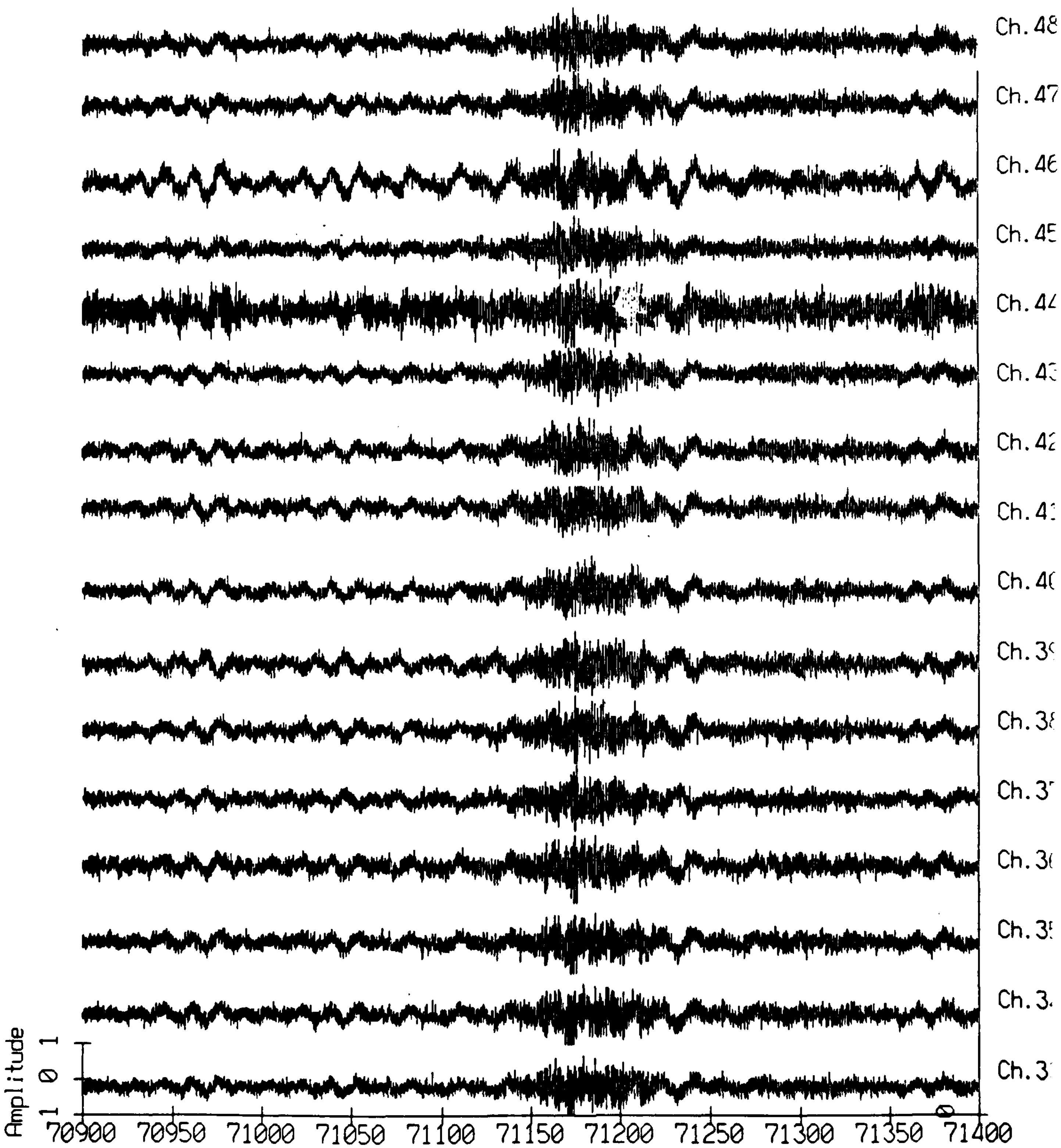


Figure VI.C.3

TAPE: sean7, Normalized time-series

Desampled every 5 points

top16VAST

Recs 70900 - 71400

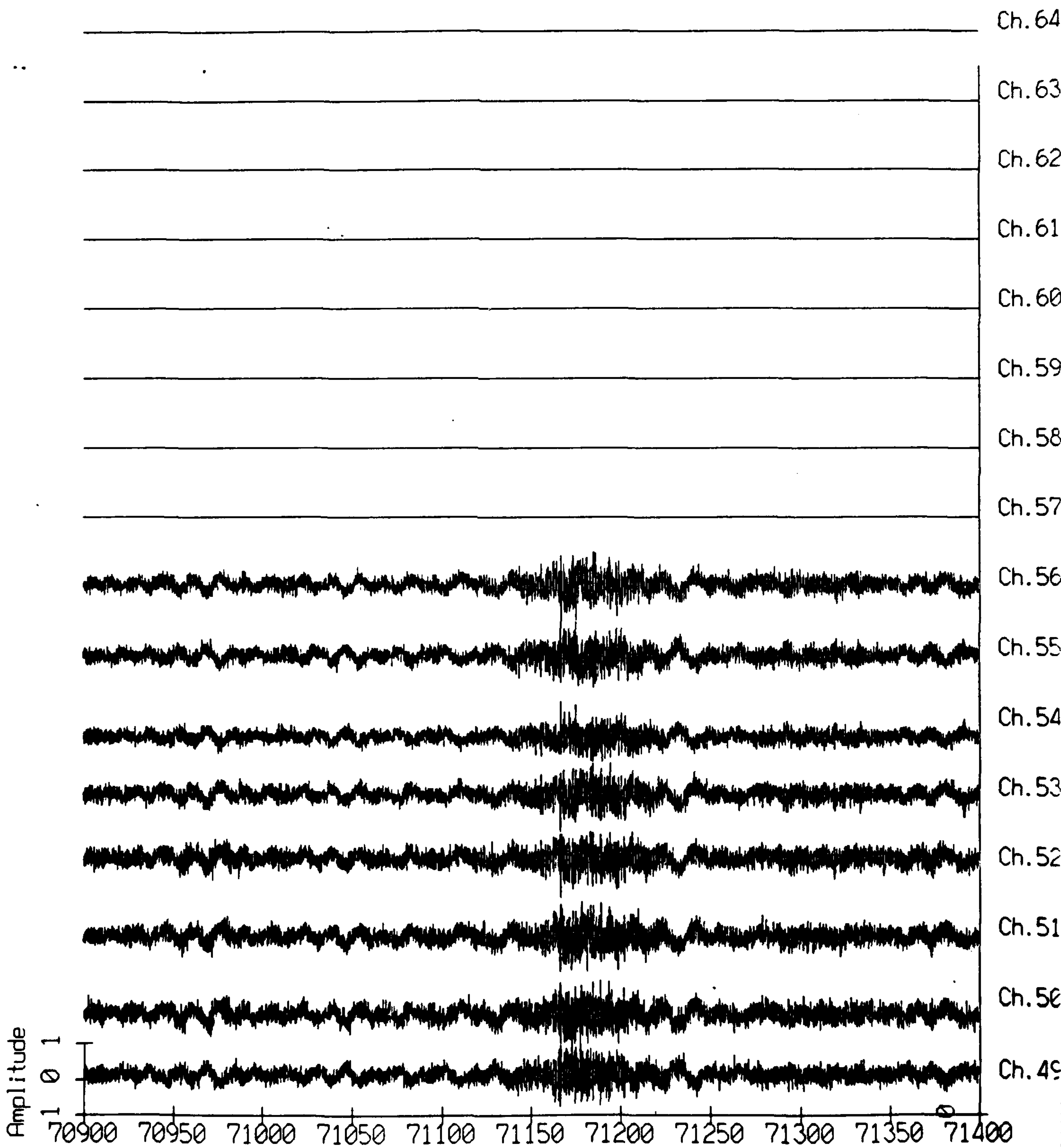


Figure VI.C.4

TAPE: sean7, Normalized time-series

bot16OBS

Desampled every 5 points

Recs 72744 - 73644

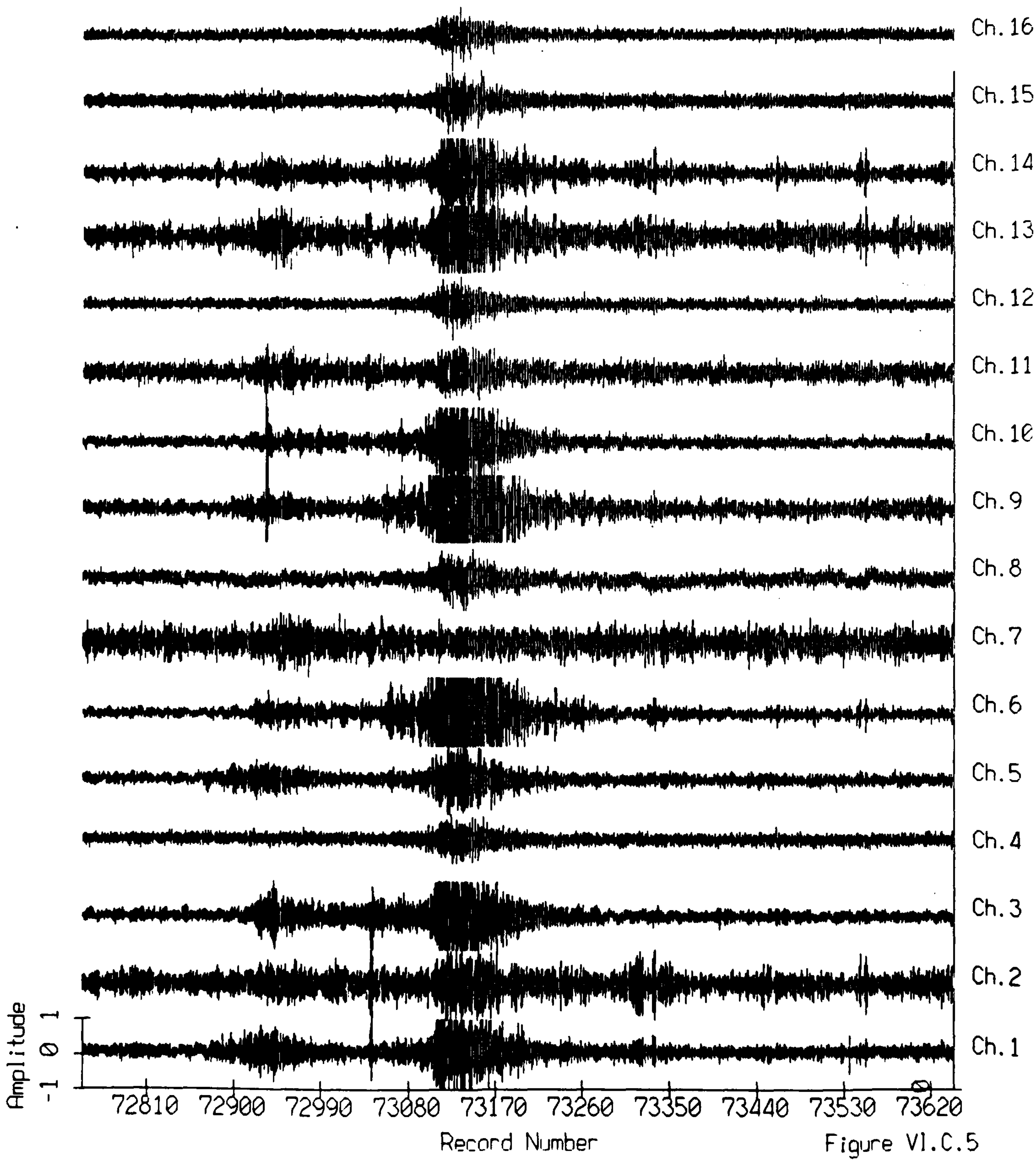
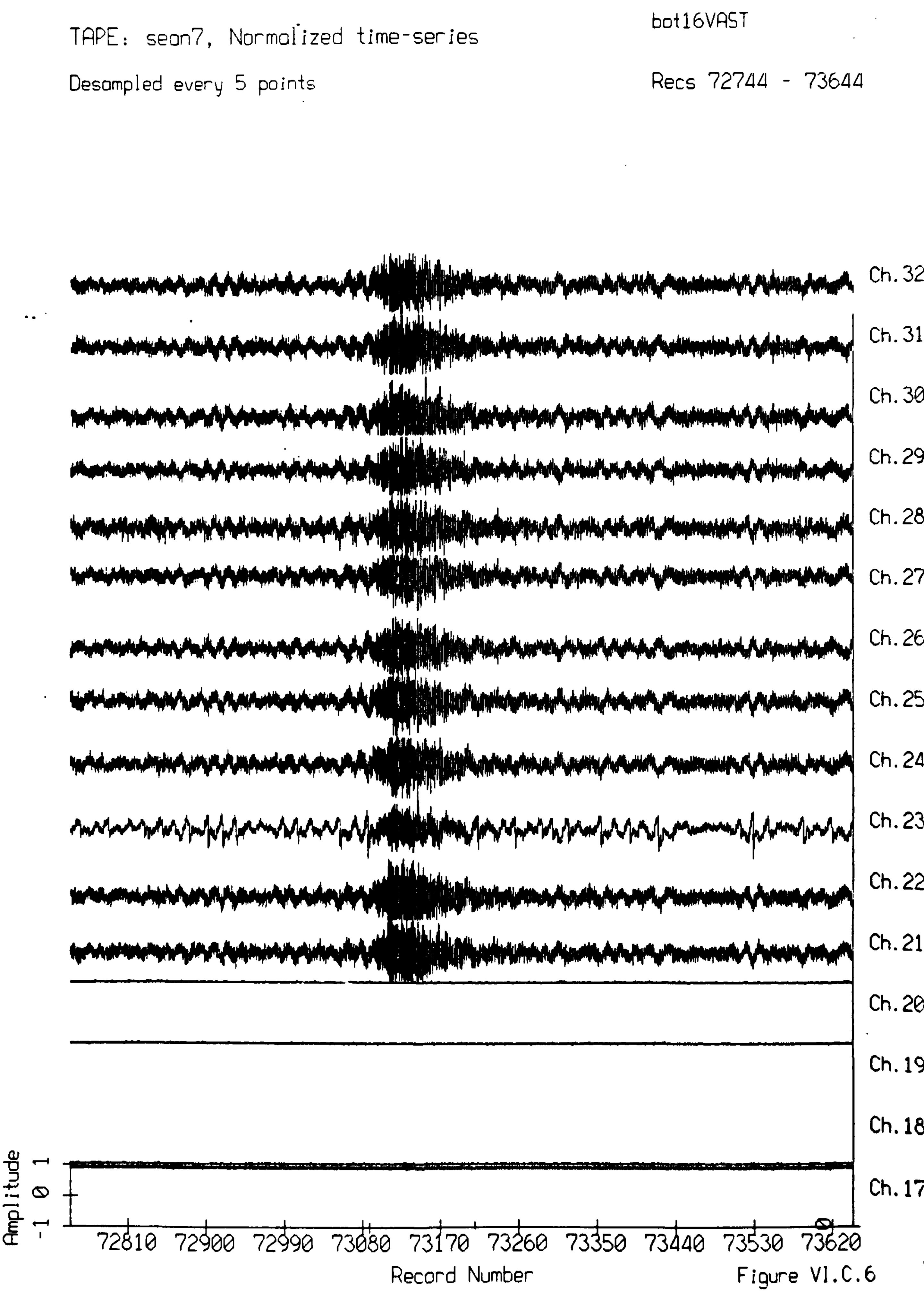


Figure VI.C.5



TAPE: seon7, Normalized time-series
bot16VAST
Desampled every 5 points
Recs 72744 - 73644
Ch. 32
Ch. 31
Ch. 30
Ch. 29
Ch. 28
Ch. 27
Ch. 26
Ch. 25
Ch. 24
Ch. 23
Ch. 22
Ch. 21
Ch. 20
Ch. 19
Ch. 18
Ch. 17
Amplitude
-1 0 1
72810 72900 72990 73080 73170 73260 73350 73440 73530 73620
Record Number

Figure VI.C.6

TAPE: seon7, Normalized time-series

mid16VAST

Desampled every 5 points

Recs 72744 - 73644

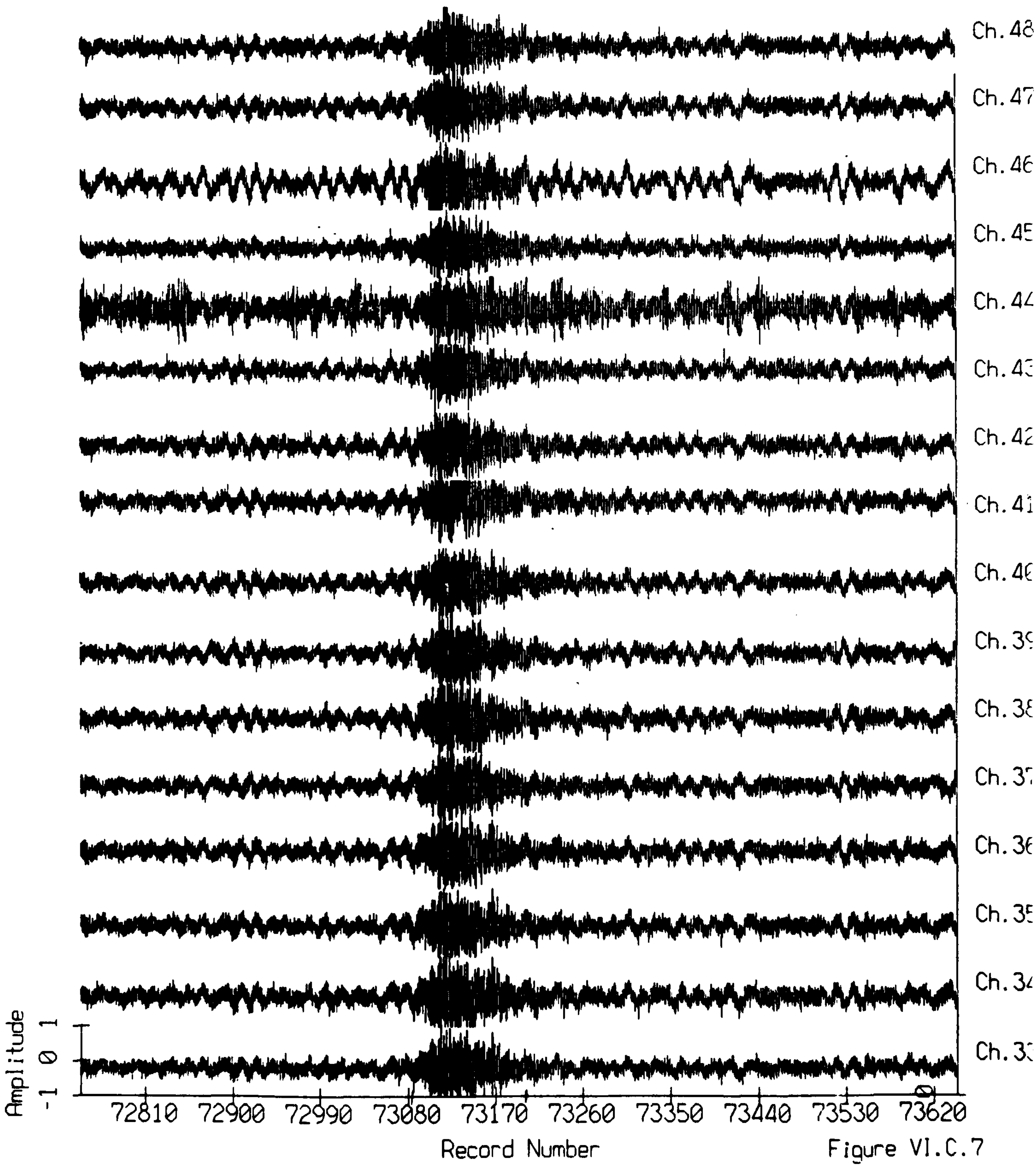


Figure VI.C.7

TAPE: seon7, Normalized time-series

top16VAST

Desampled every 5 points

Recs 72744 - 73644

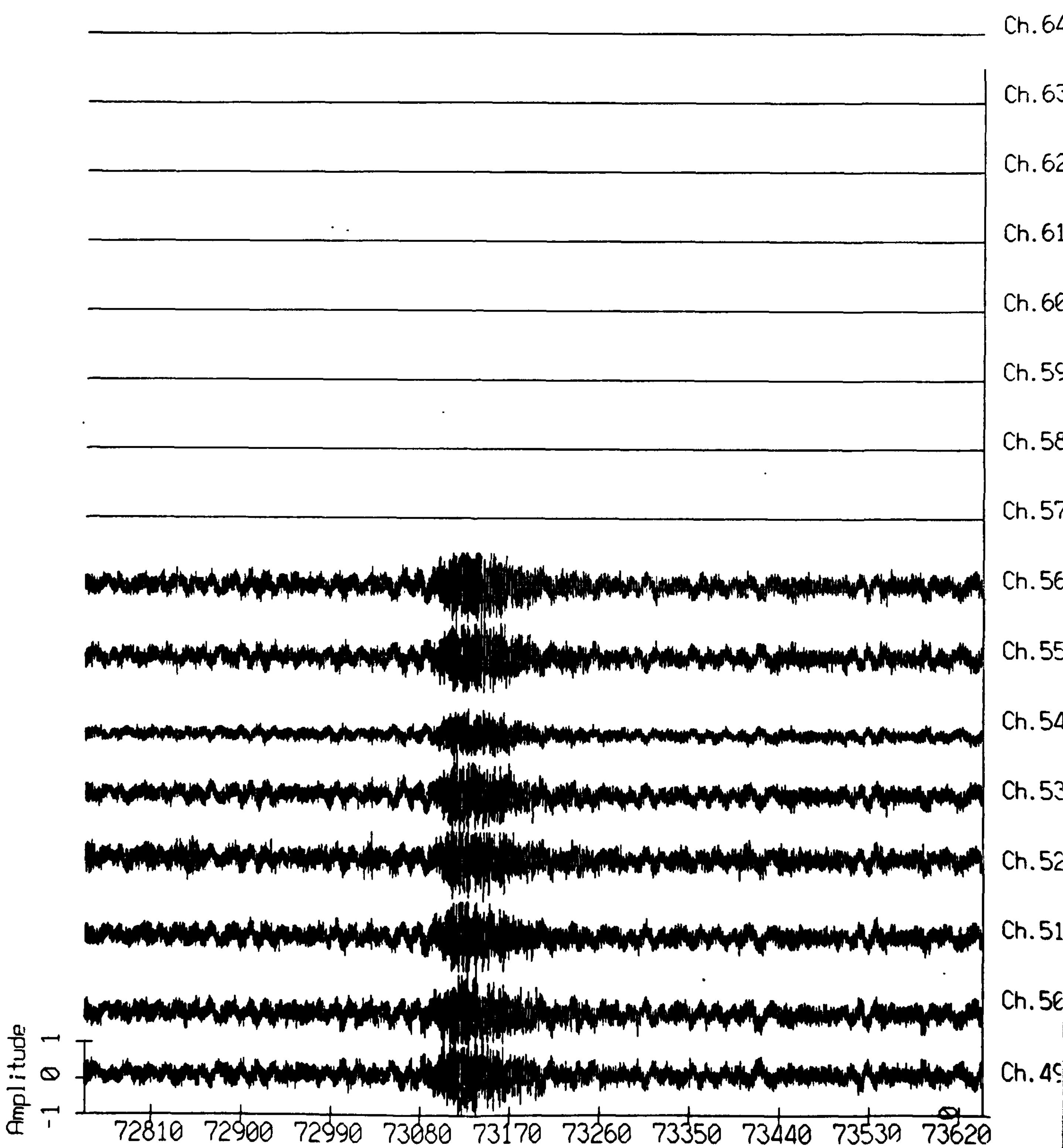


Figure VI.C.8

TAPE: sean7, Normalized time-series

Desampled every 5 points

bot16OBS

Recs 91000 - 91900

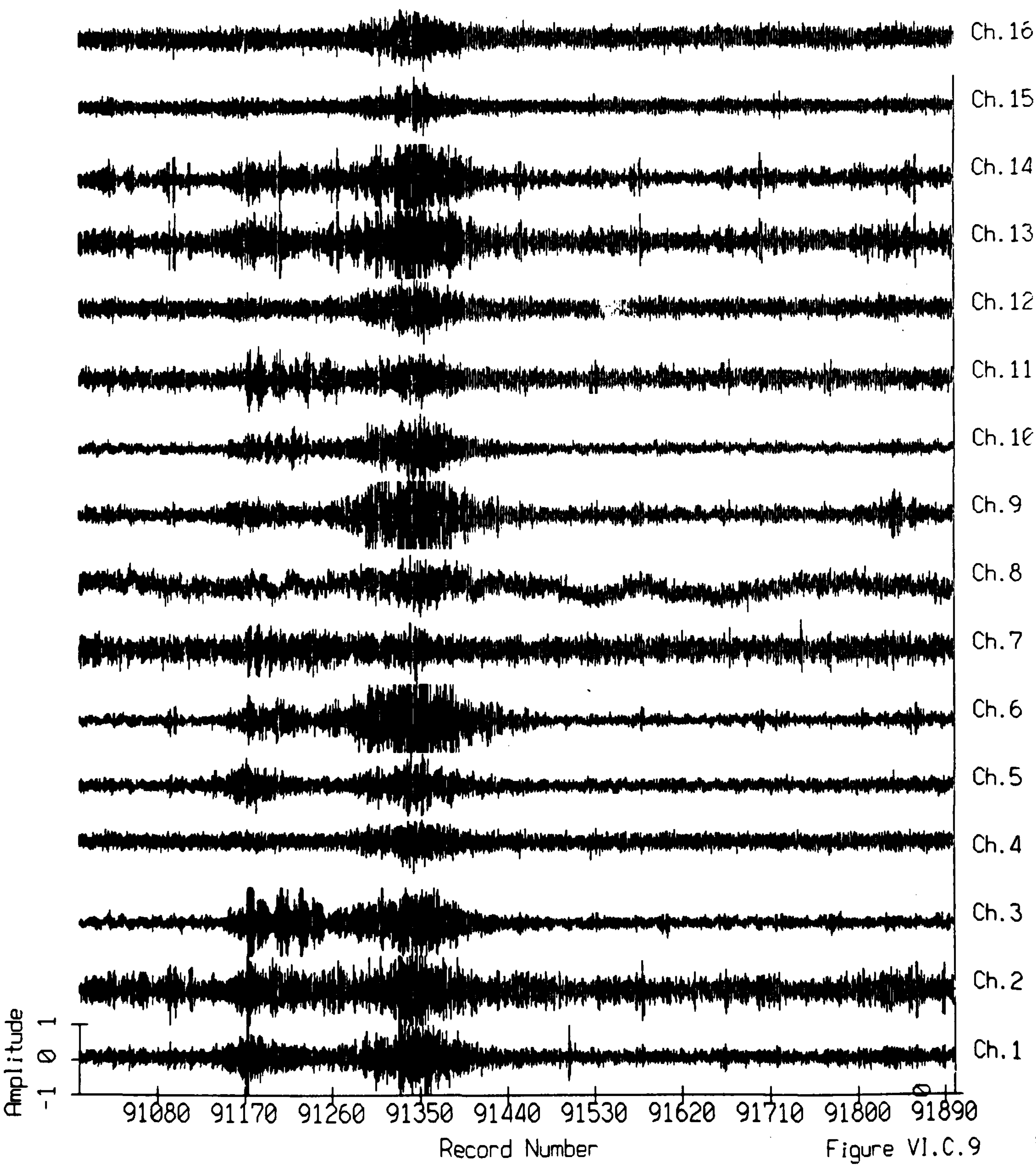


Figure VI.C.9

TAPE: seon7, Normalized time-series

Desampled every 5 points

bot16OBS

Recs 95200 - 96100

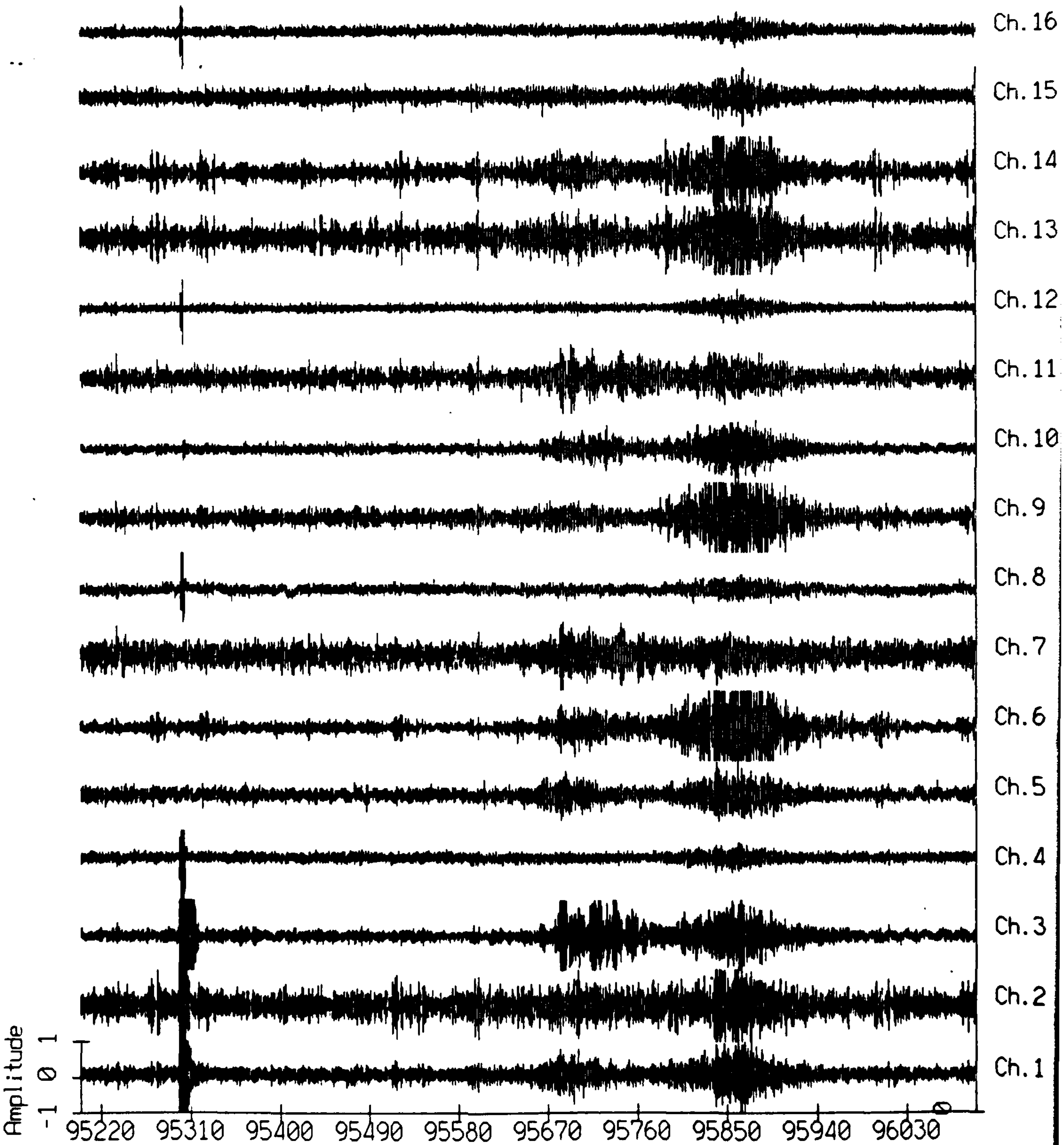


Figure VI.C.10

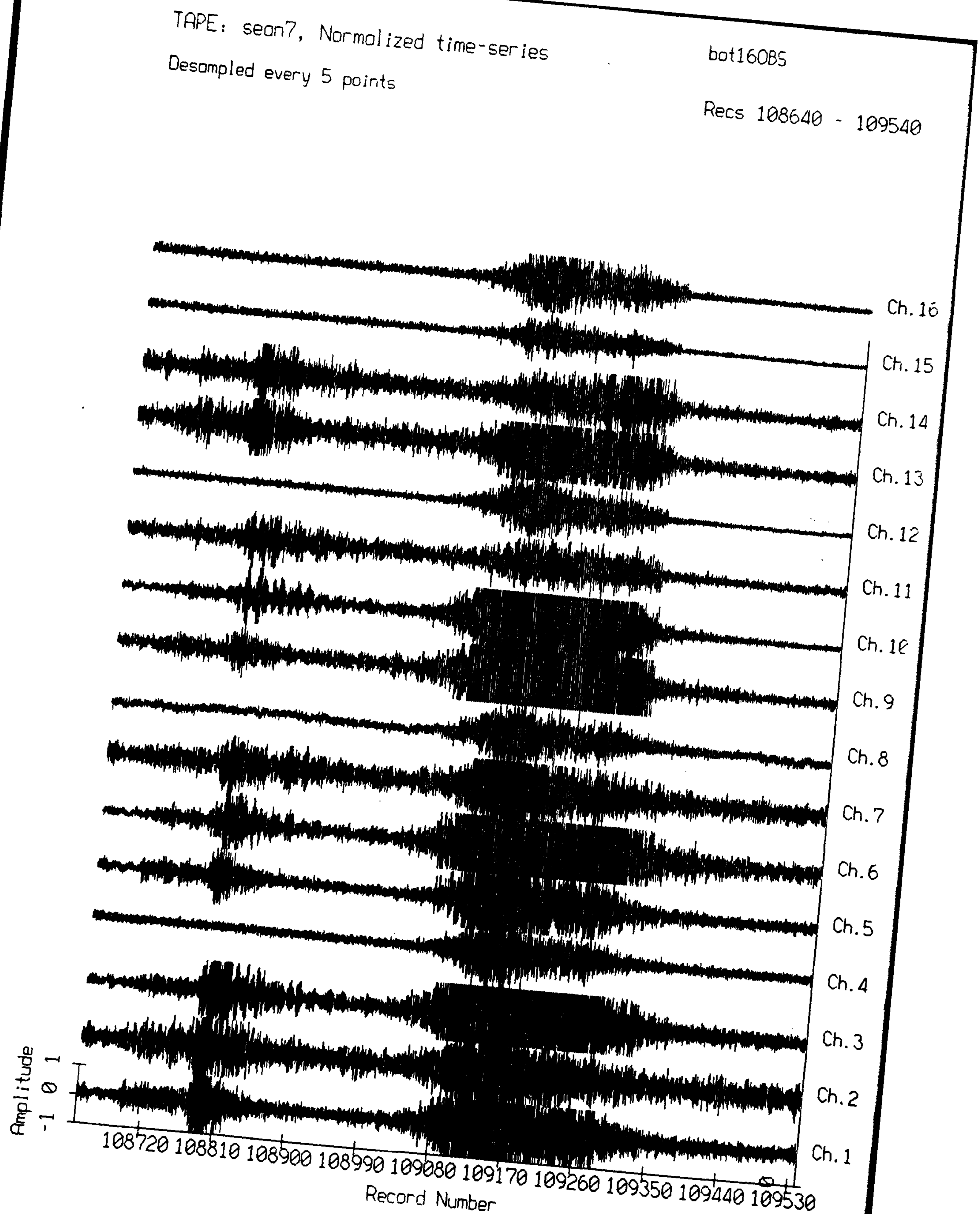


Figure VI.C.11

TAPE: sean7, Normalized time-series

Desampled every 5 points

bot16VAST

Recs 108640 - 109540

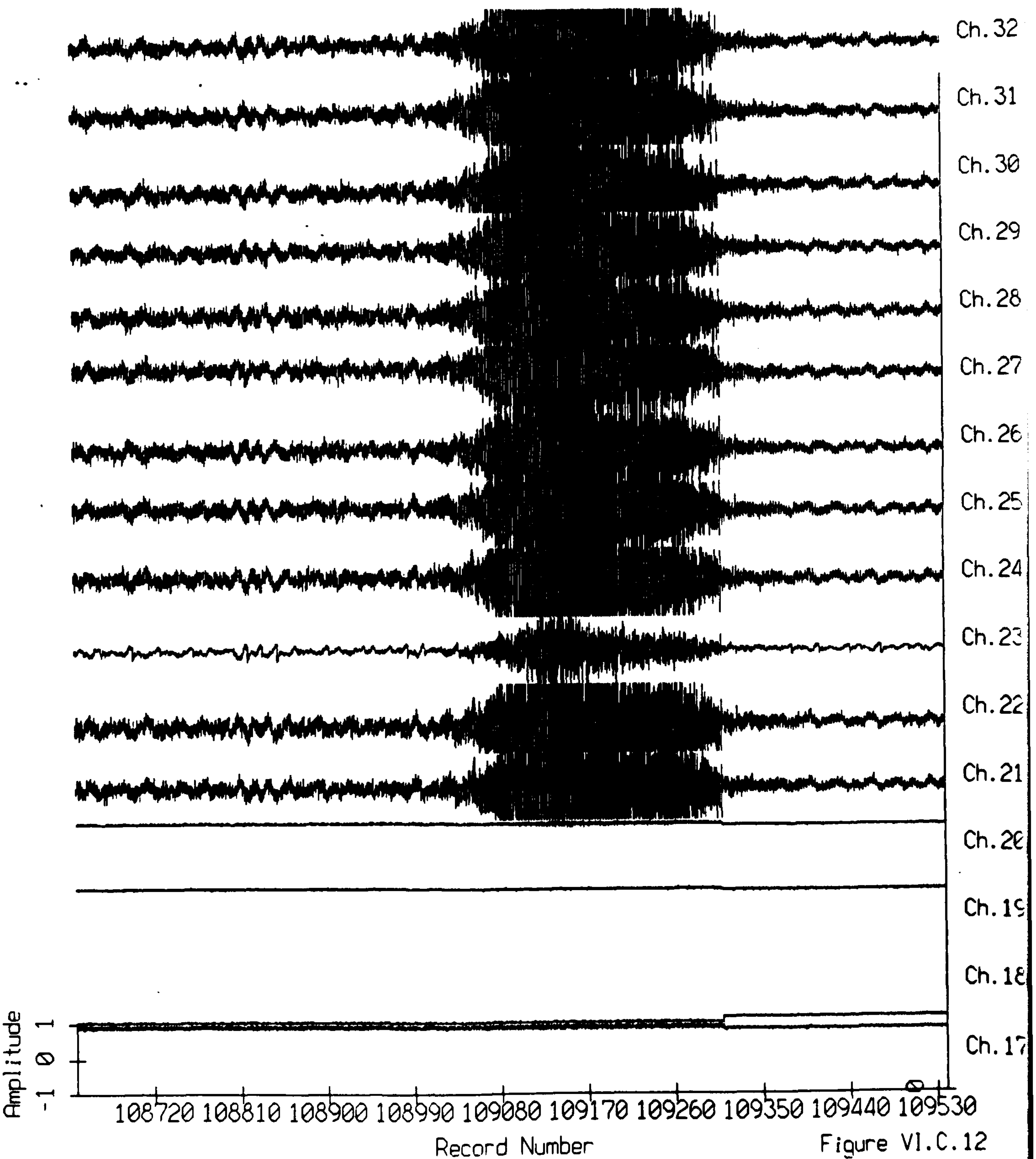


Figure VI.C.12

TAPE: sean7, Normalized time-series

Desampled every 5 points

mid16VAST

Recs 108640 - 109540

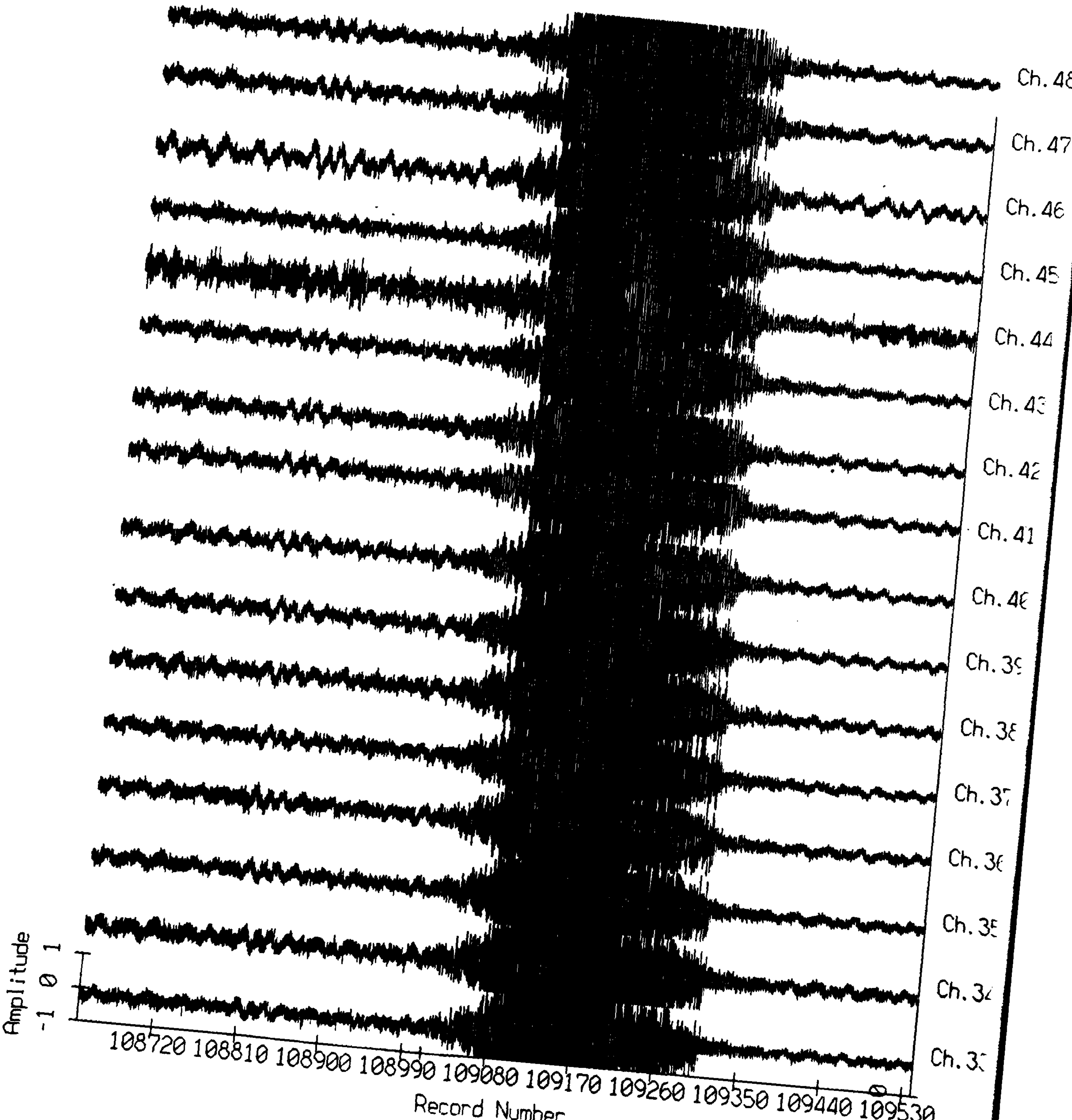


Figure VI.C.13

TAPE: seon7, Normolized time-series

Desompled every 5 points

top16VAST

Recs 108640 - 109540

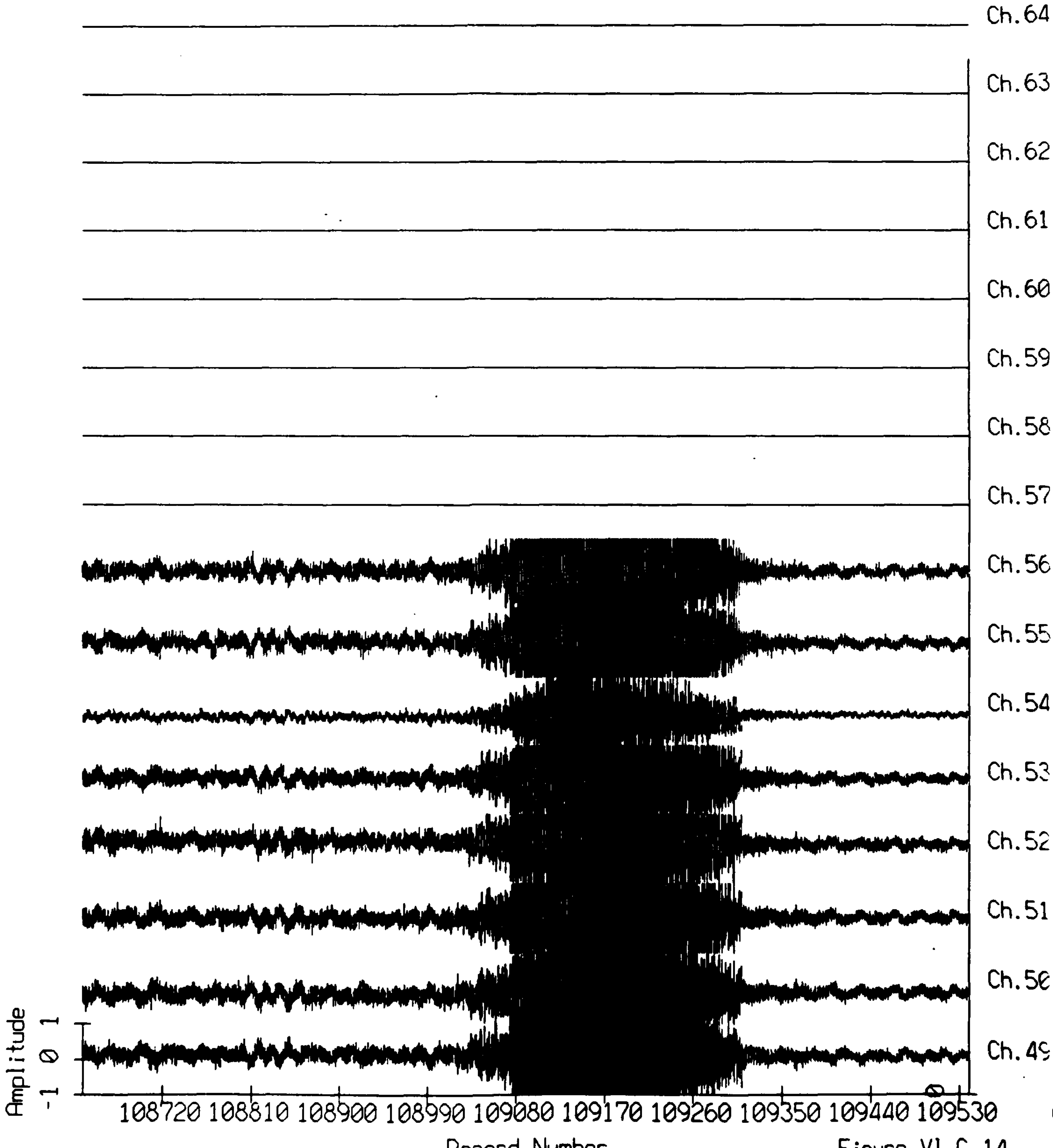


Figure VI.C.14

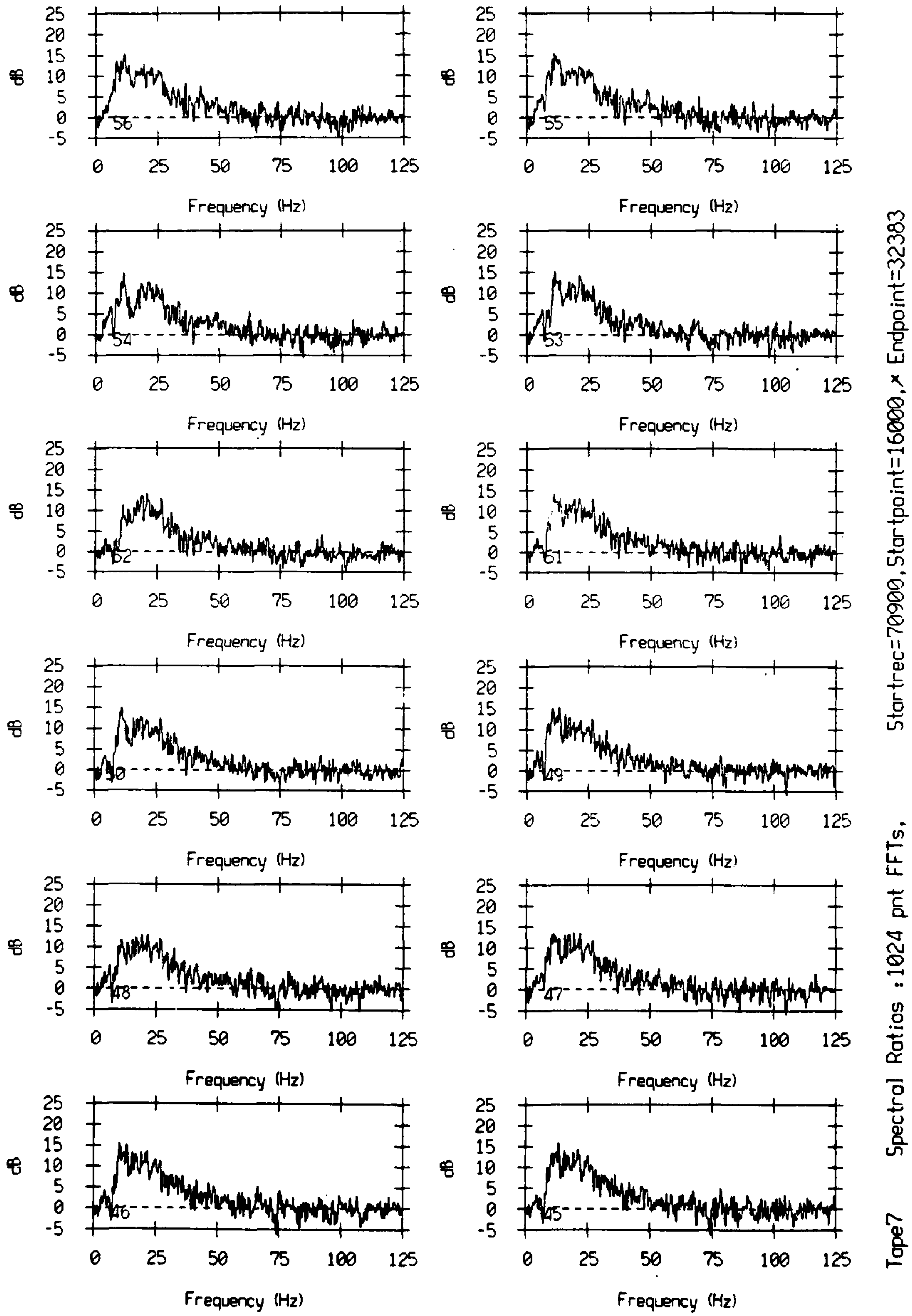


Figure VI.C1.1

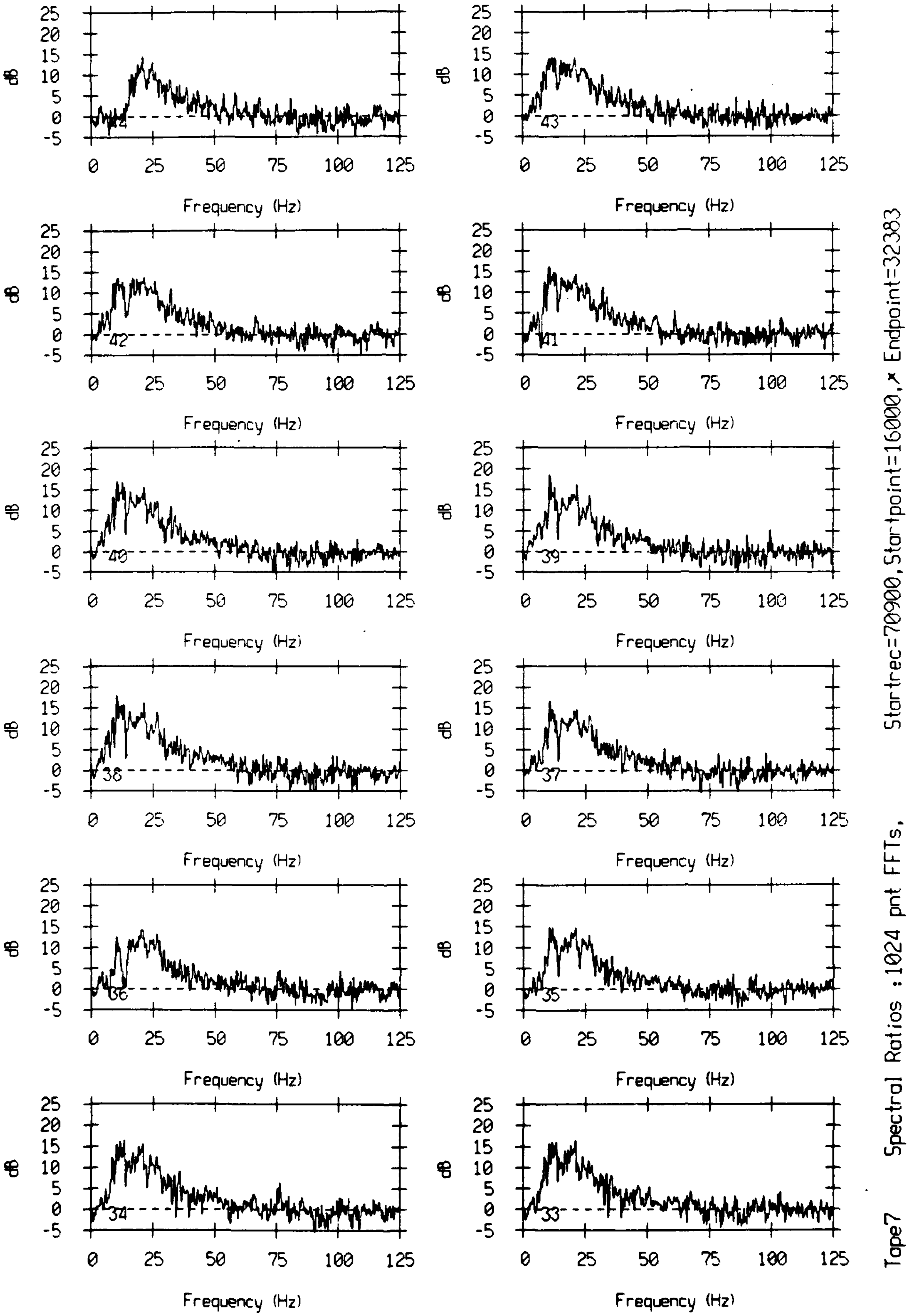


Figure VI.C1.2

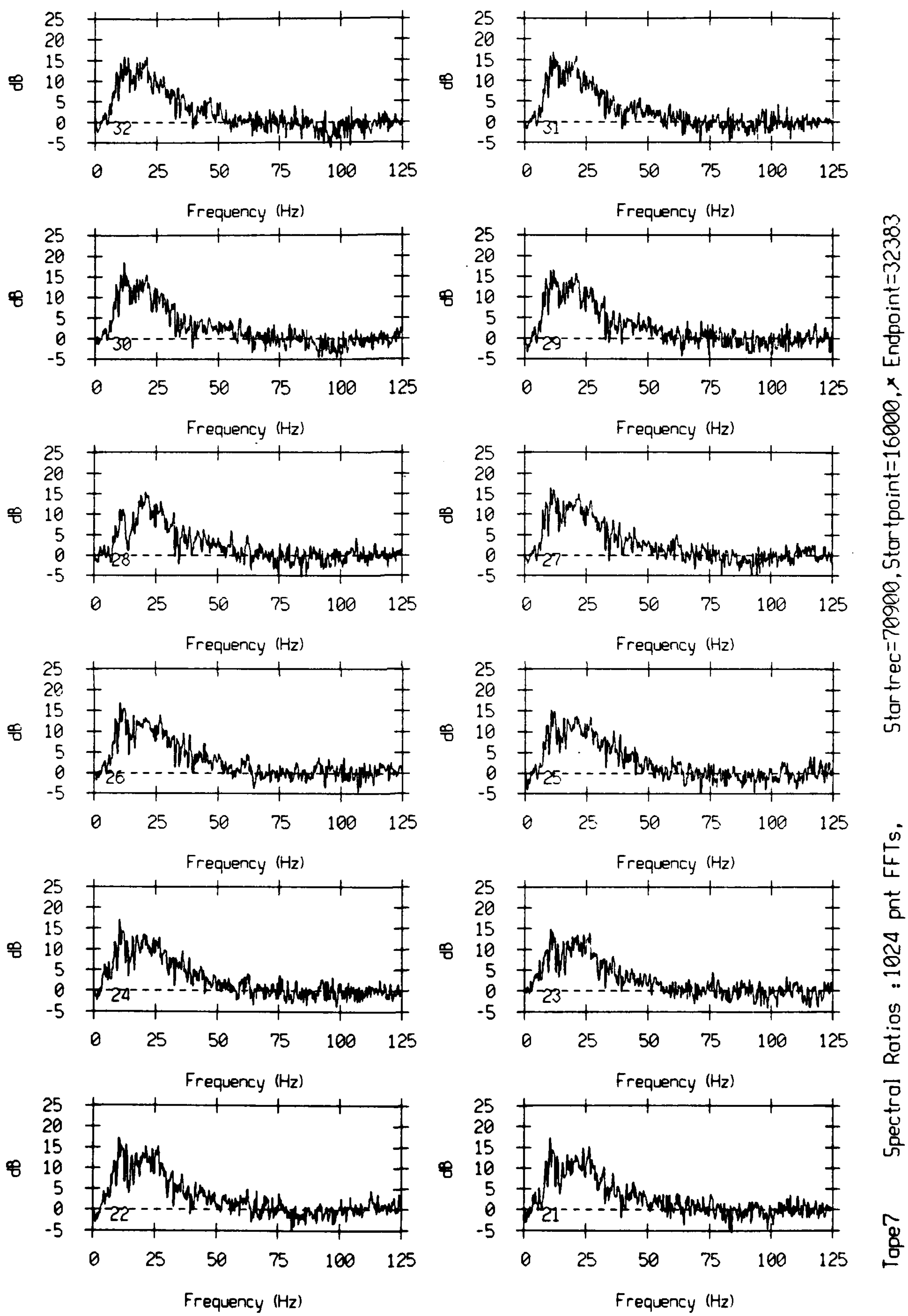


Figure VI.C1.3

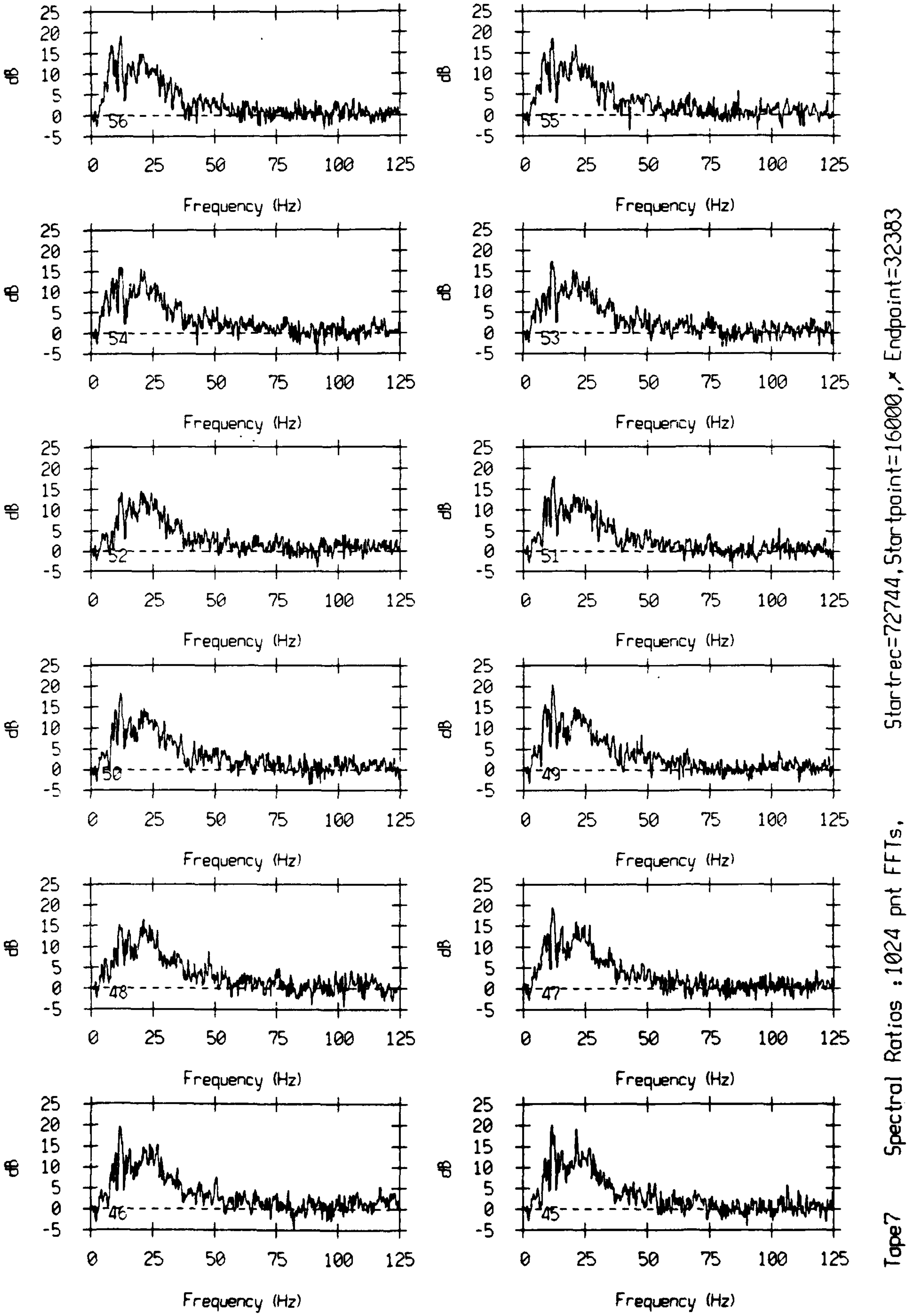


Figure VI.C1.4

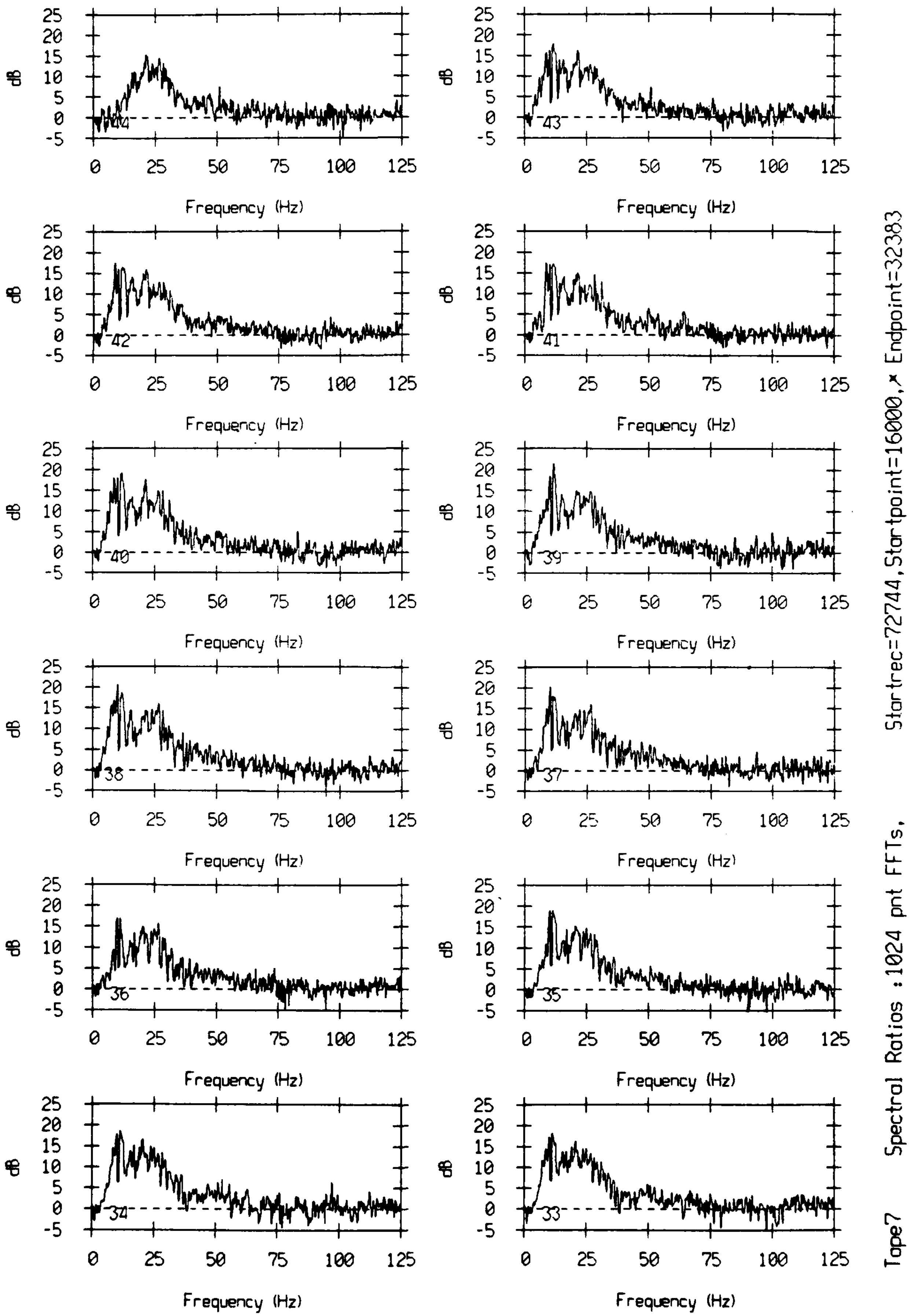


Figure VI.C1.5

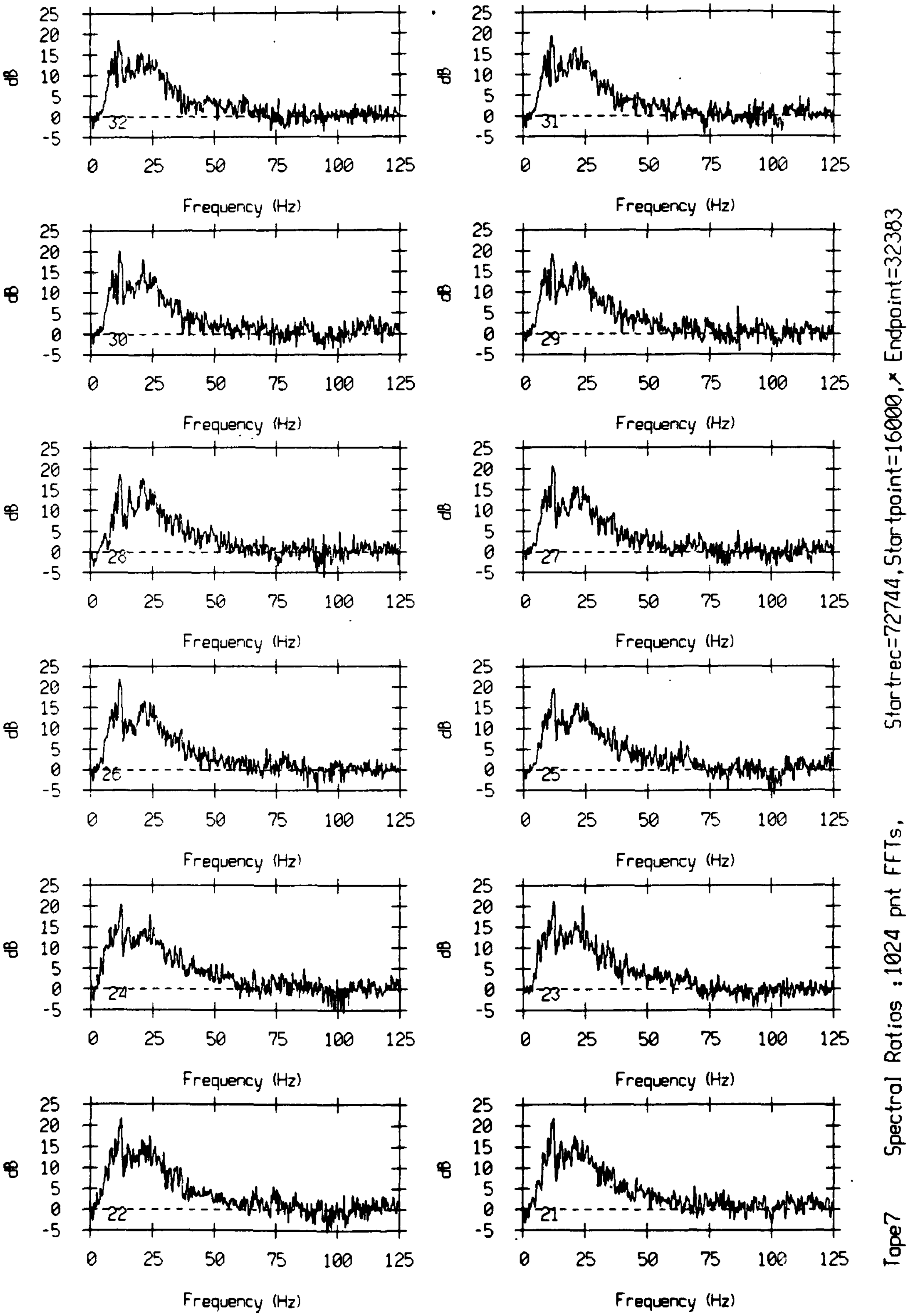


Figure VI.C1.6

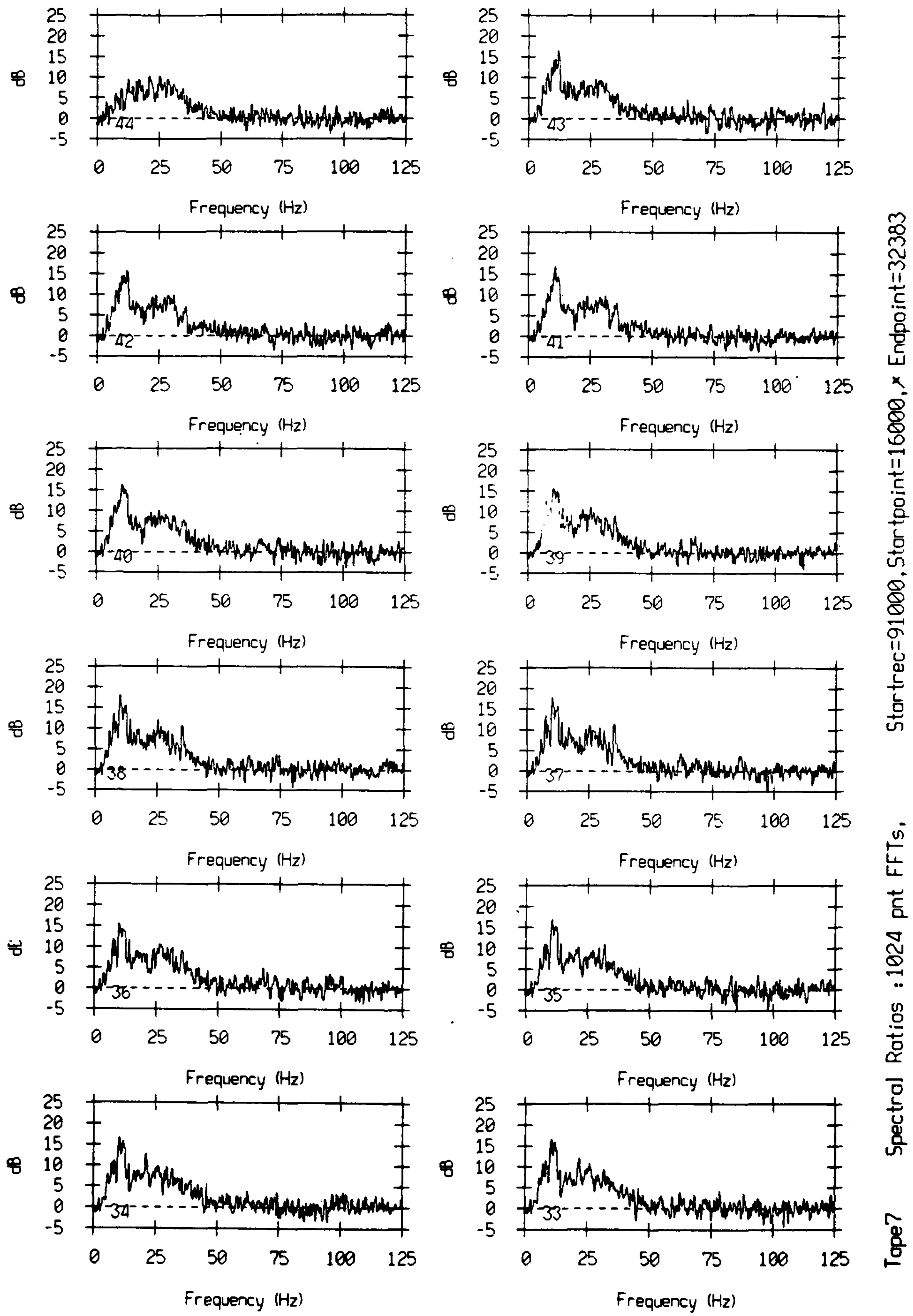
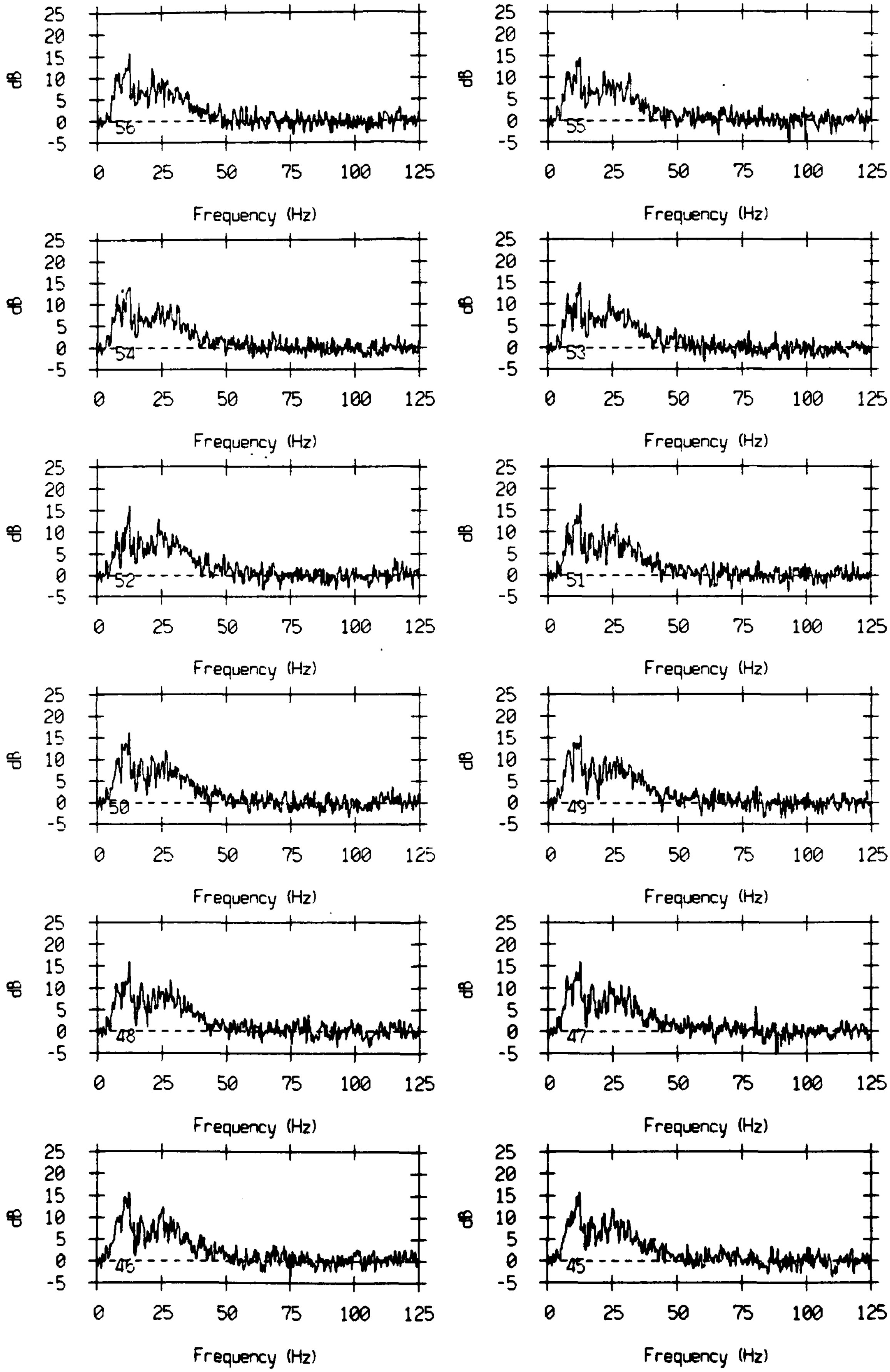


Figure VI.C1.7



Tape7 Spectral Ratios :1024 pnt FFTs, Startrec=91000, Startpoint=16000, Endpoint=32383

Figure VI.C1.8

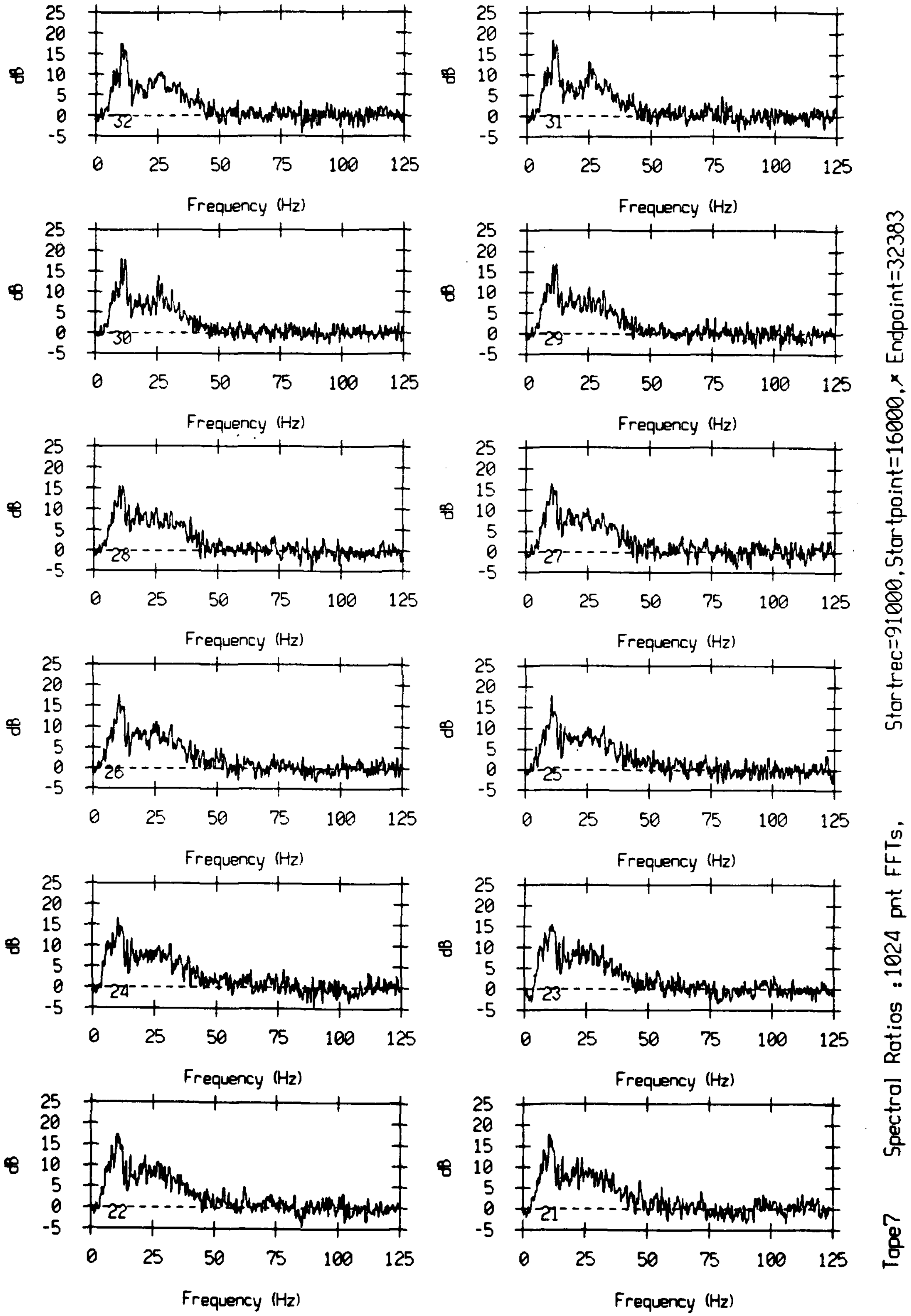


Figure VI.C1.9

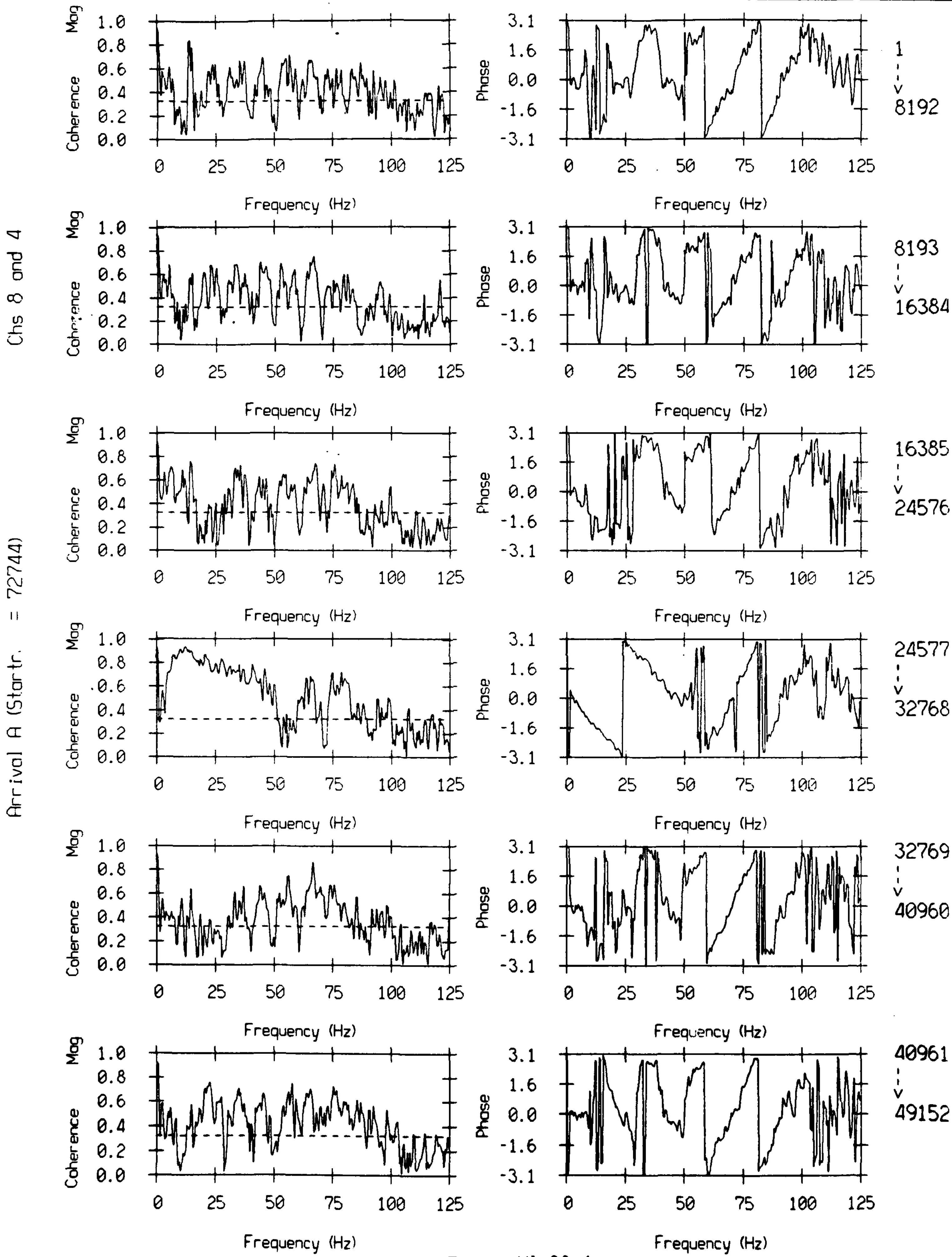


Figure VI.C2.1

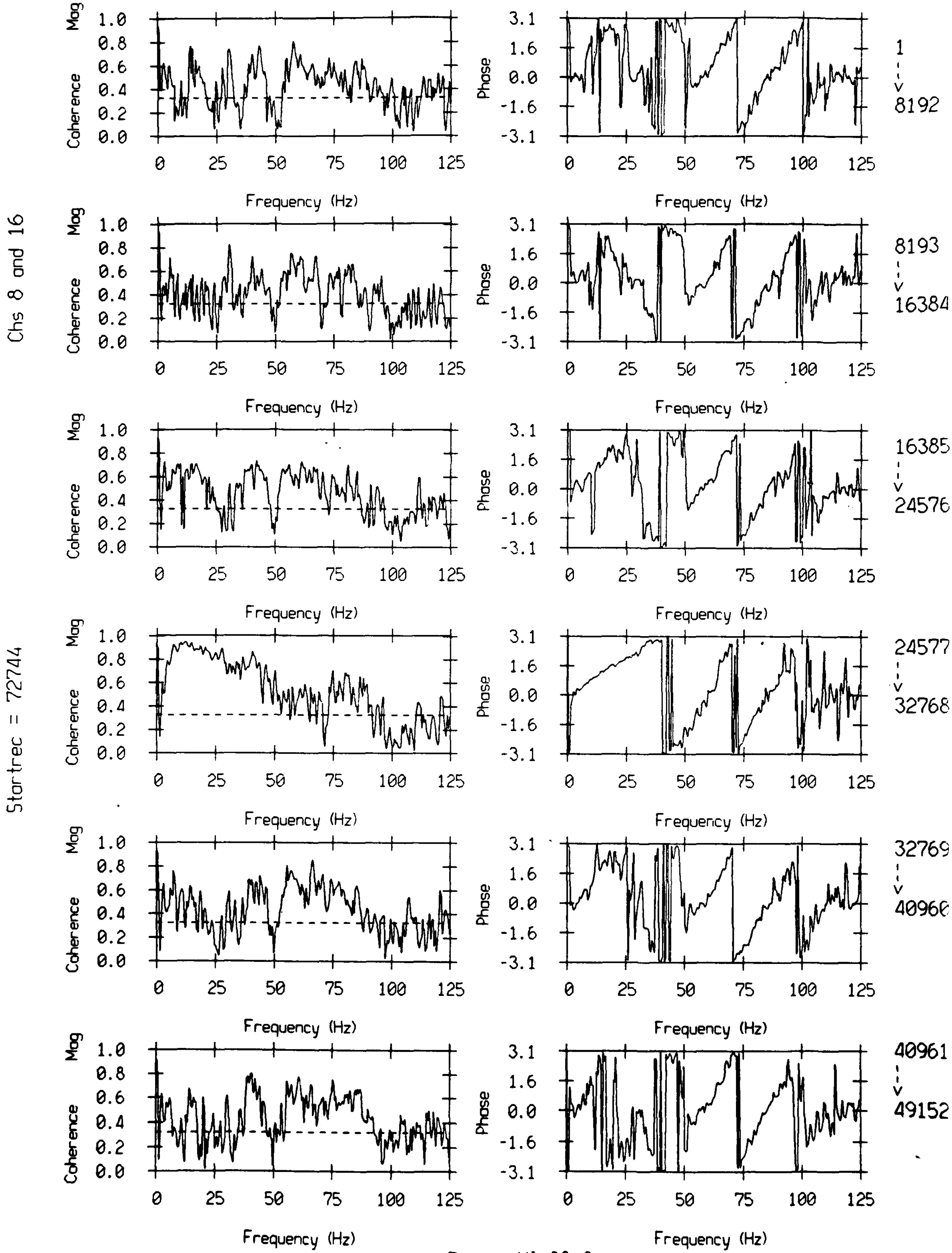


Figure VI.C2.2

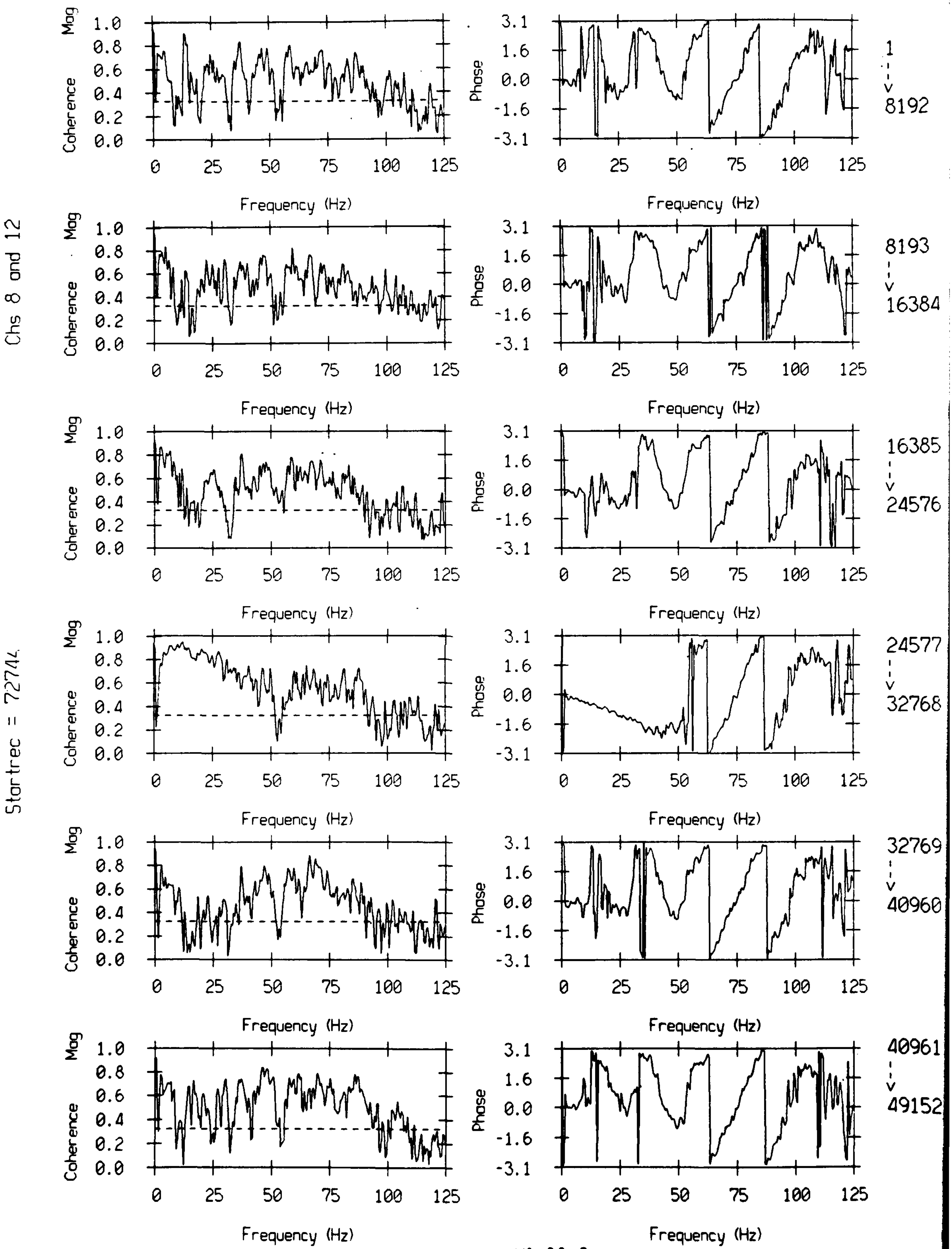


Figure VI.C2.3

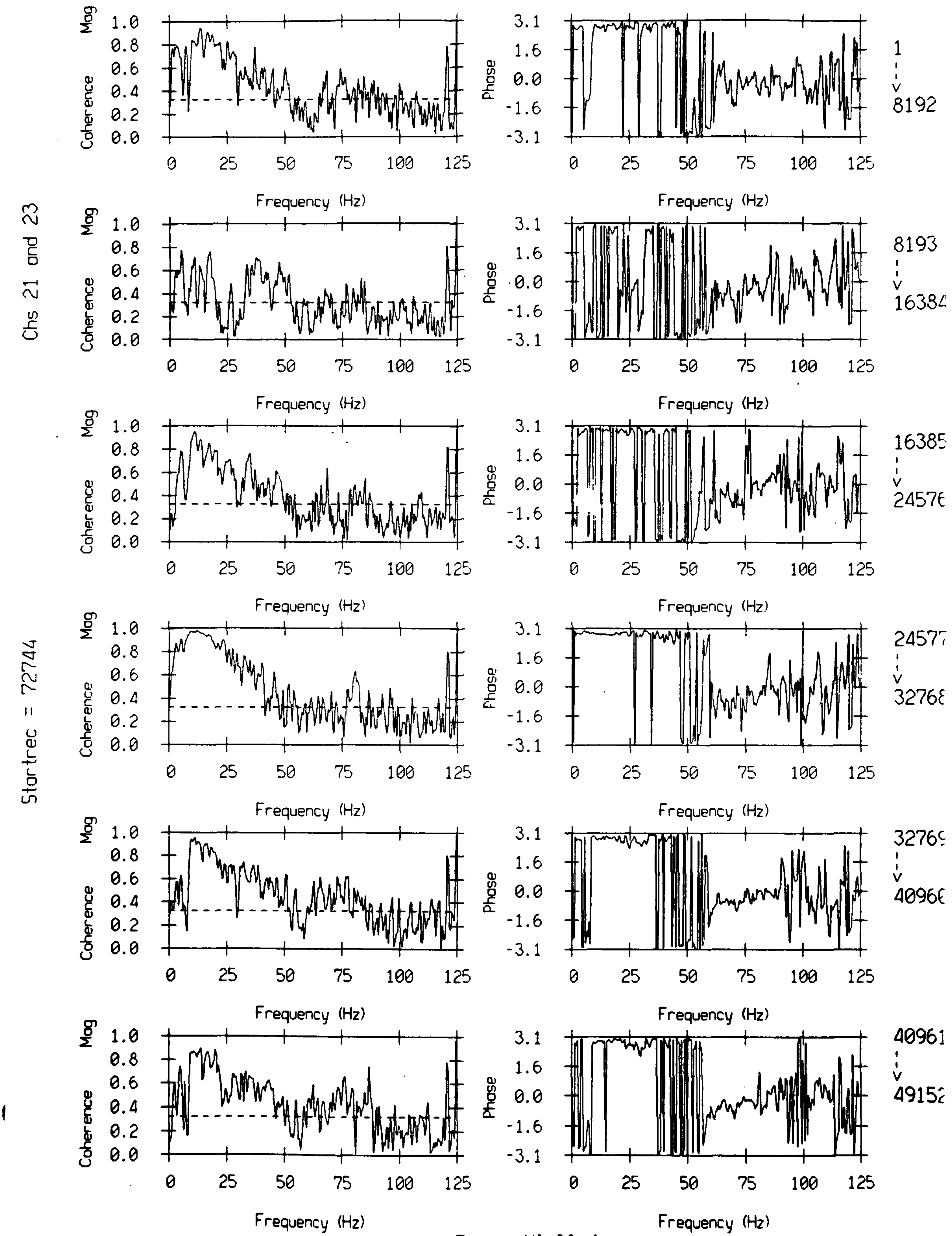


Figure VI.C2.4

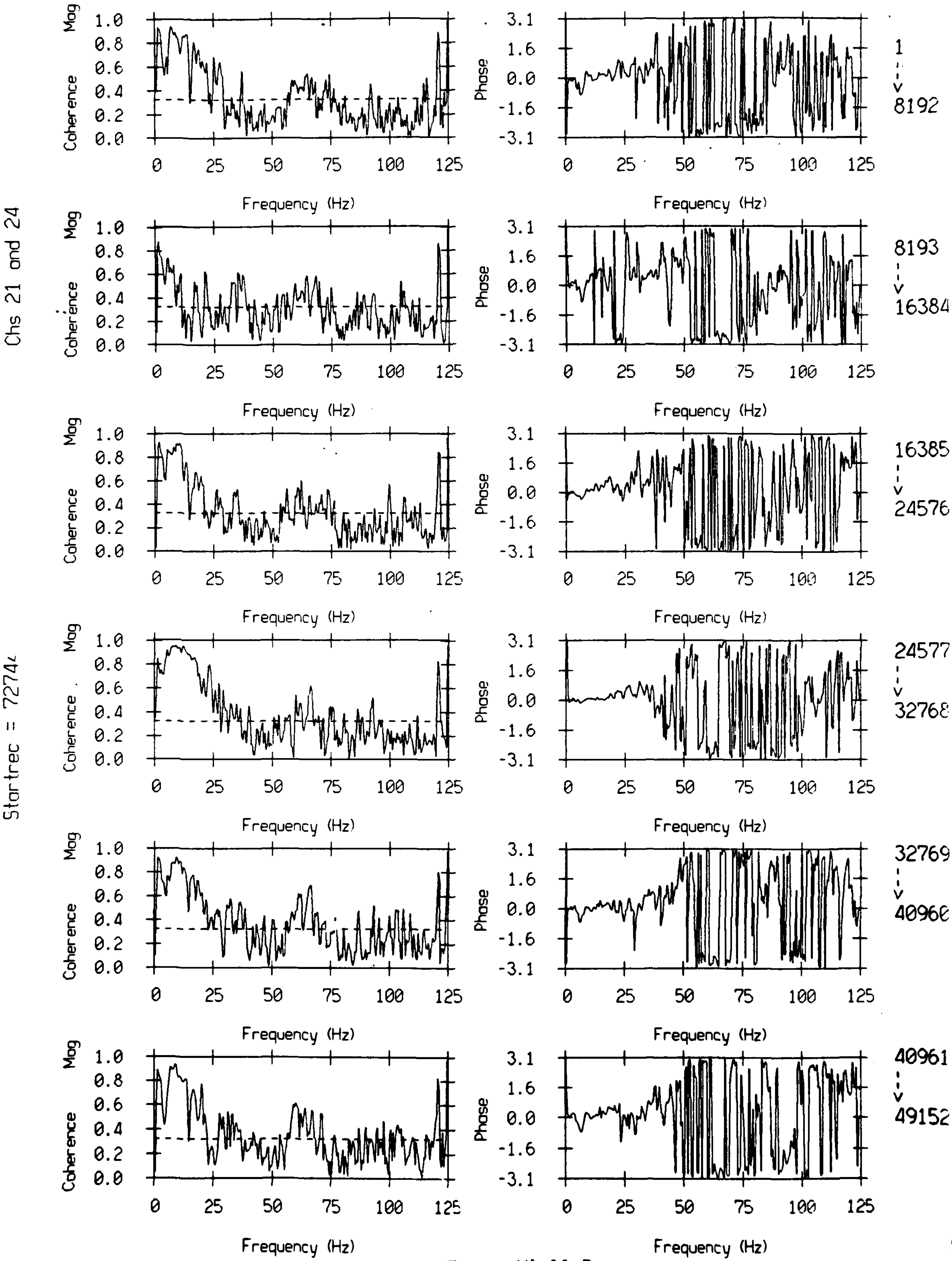


Figure VI.C2.5

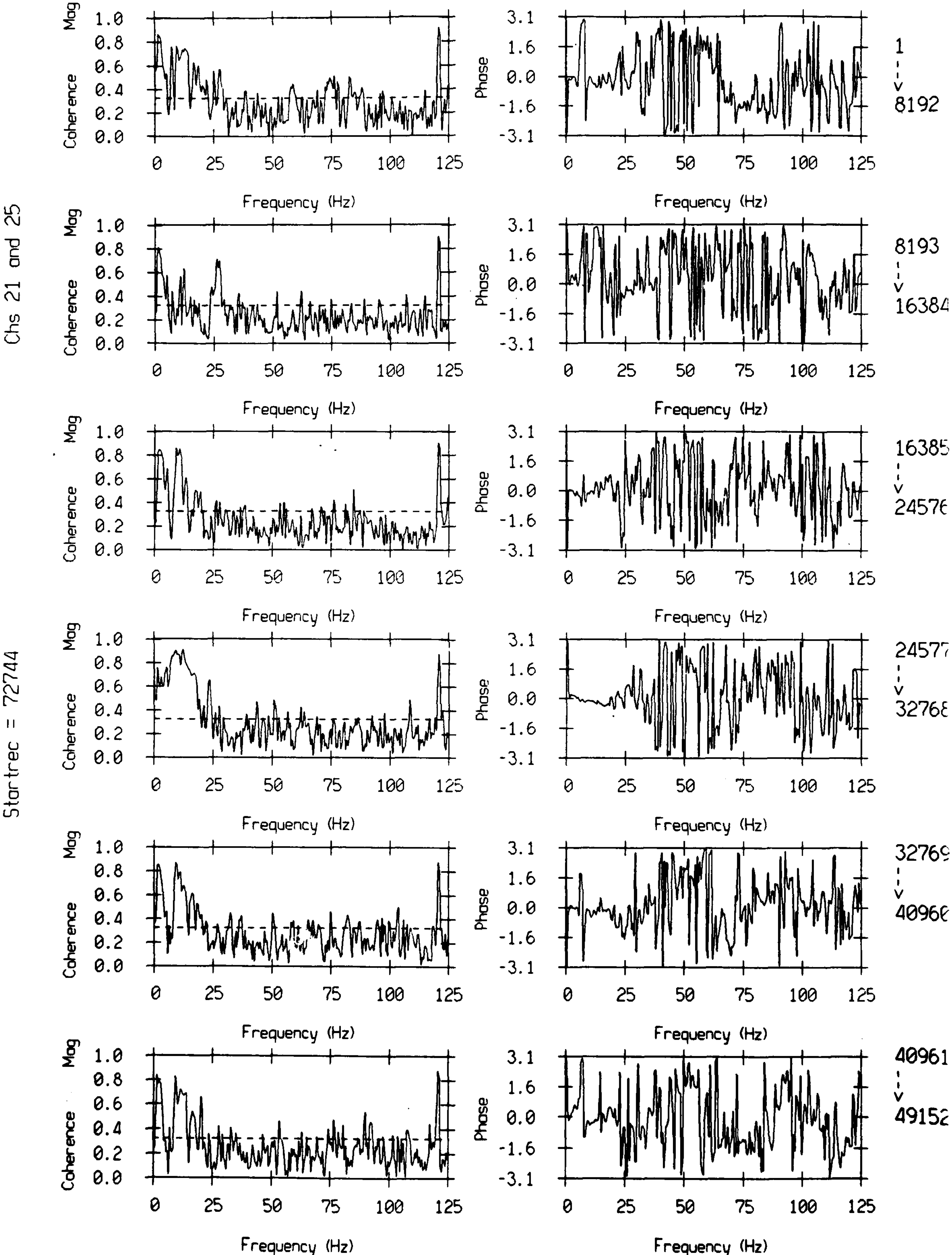


Figure V1.C2.6

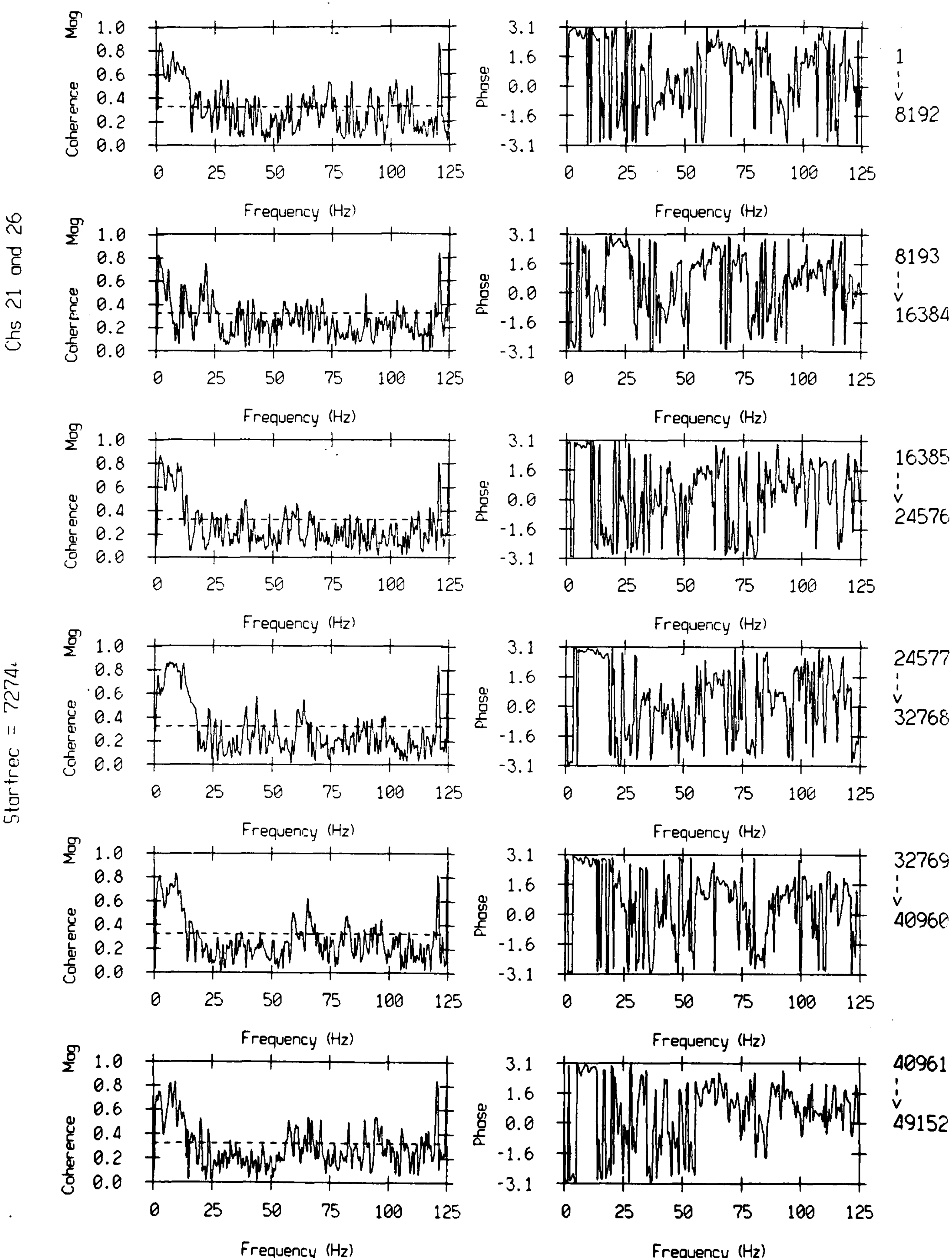


Figure VI.C2.7

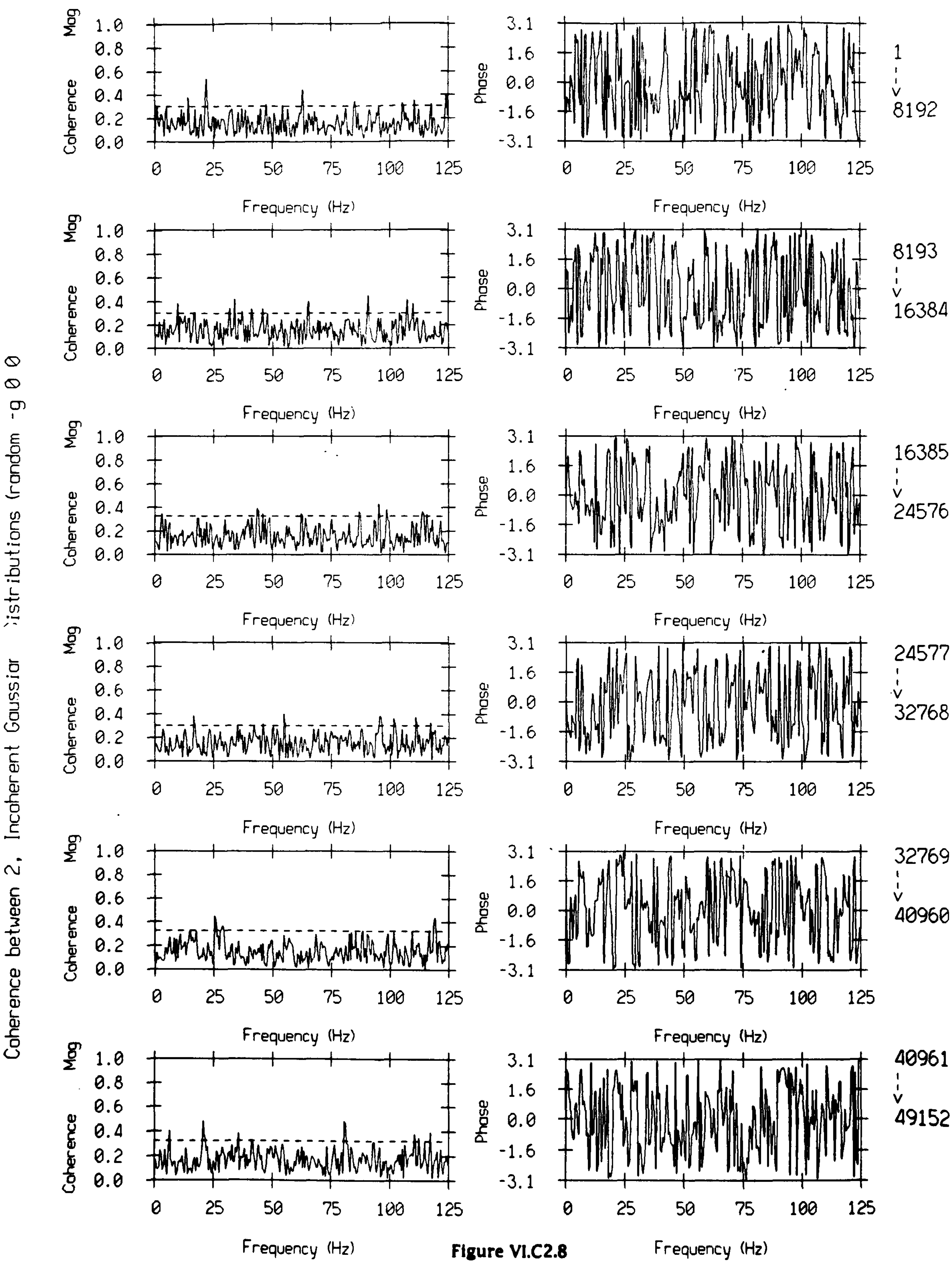


Figure VI.C2.8

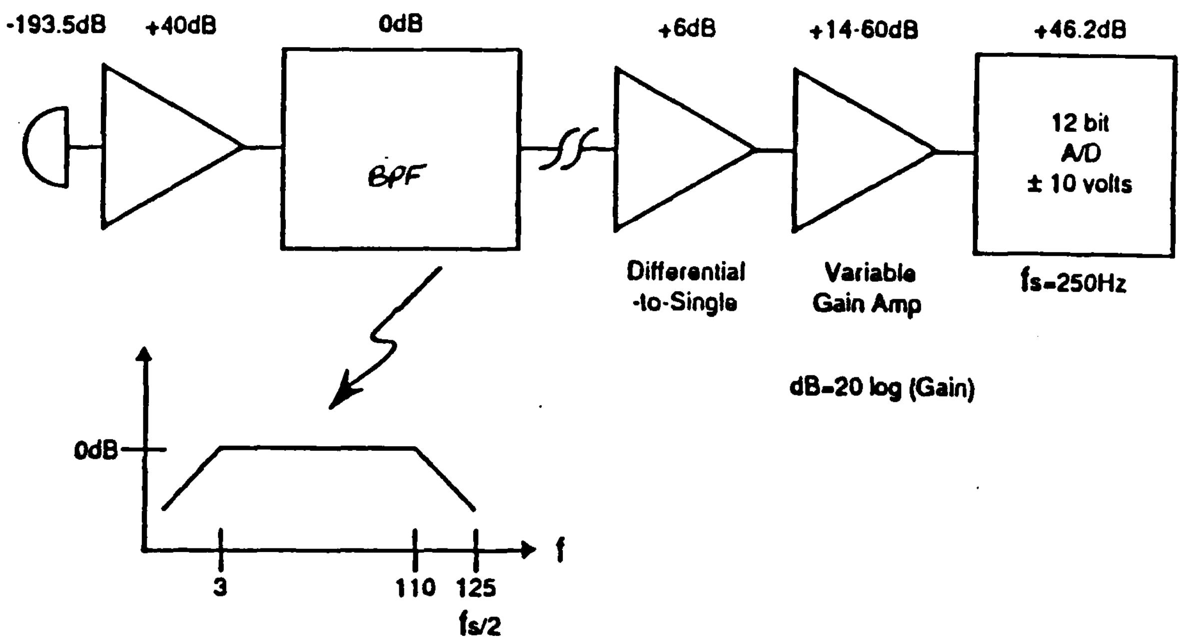
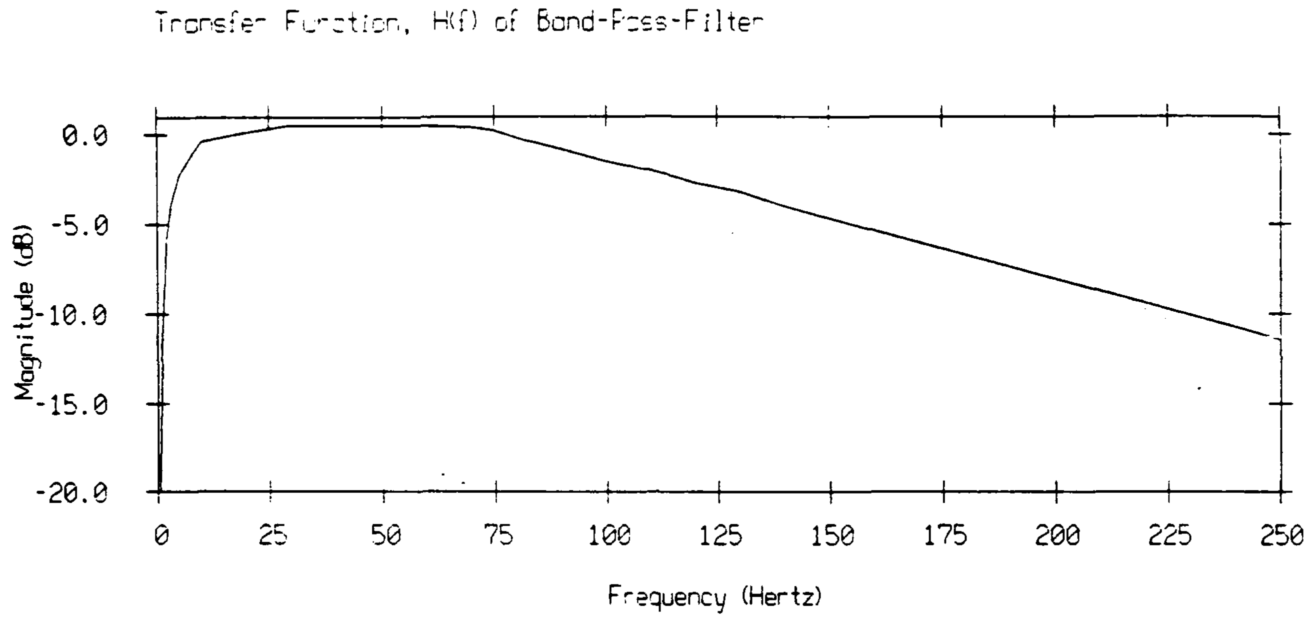
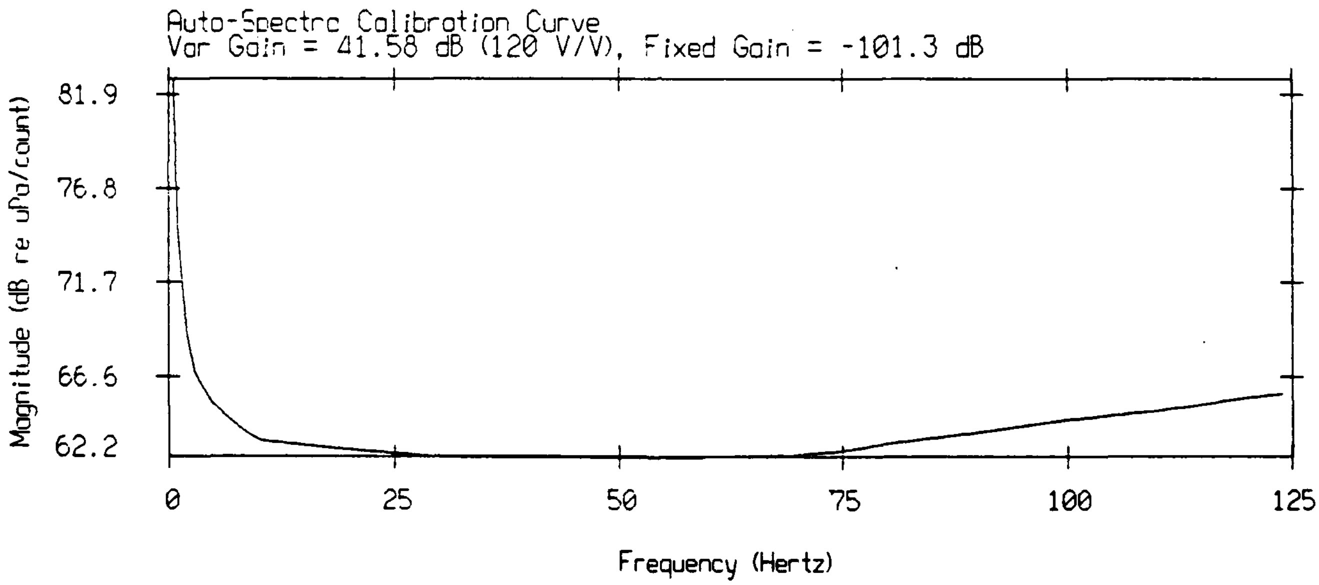

-193.5dB
+40dB
0dB
+6dB
+14-60dB
+46.2dB
BPF
12 bit
A/D
± 10 volts
Differential
-to-Single
Variable
Gain Amp
fs=250Hz
dB=20 log (Gain)
0dB
f
3
110
125
fs/2

Figure A.1





10log(outfile)= - [Fixed Gain + Var Gain +* Interpolated H(f)] + 3

Figure A.2

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